3. SITE, FACILITY AND OPERATIONS DESCRIPTION

A. ORGANIZATION

Figure 3-B-1 shows the organization among the Department of Energy the prime contractor Brookhaven Science Associates (BSA), Brookhaven National Laboratory (BNL), and RHIC. Figure 3-B-2 is the typical organization chart for BNL that shows the management lines of reporting.

Construction activities of the RHIC Project and routine day-to-day operations follow the typical ES&H reporting lines of authority shown in Figure 3-B-3. During Commissioning without beam, the Cryogenic Control Room has been designated as the place where supervisors shall coordinate their activities. The Cryogenic Shift Supervisor has the authority to be the overall coordinator for the complex. These lines of management authority are defined in RHIC OPM 2.0 RHIC Operations, Organization and Administration During Periods Without Beam.

During periods of Commissioning with beam, the AGS Conduct of Operations applies to the entire RHIC and AGS Complexes and is defined in AGS OPM 2.1 Operations, Organization and Administration. The organization chart for Commissioning is shown in Figure 3-B-4.

At such time when the RHIC Project is completed and the organization and facilities are consolidated with the AGS Department into the Collider Accelerator Department, the new Department will be organized in accordance with Figure 3-B-5. The operational configuration of the new Department will remain as Figure 3-B-4.

The DOE Brookhaven Area Group (BHG) provides oversight for DOE with reviews and approvals on construction and technical areas.

Other support groups throughout the Laboratory, such as shop, fiscal, management information, safety and procurement, provide service to the Project as needed.

ES&H Review Process

The RHIC Project Director is responsible to ensure all aspects of construction and commissioning are reviewed for ES&H so as to comply with regulatory and BNL requirements. This is best achieved by conducting reviews at the design stage. To assist designers, a Systems Safety

Engineer from the Safety and Health Services Division is dedicated to the Project to carry out safety engineering as part of the Collider and Detector design process.

To cover the wide range of ES&H issues that impact the RHIC Complex, six safety committees were appointed and charged with specific responsibilities promulgated in the Operations Procedures Manual. In addition to the safety committees, any modifications or additions to infrastructure that does not fall under the defined oversight roles described below are submitted for review by the Safety and Health Services Division. Recommendations from each Committee are tracked by the RHIC Project Office ES&H Office and verified by Operational Readiness Reviews. When the required actions are complete, the Project Director then gives permission to operate in writing to the cognizant Associate Director or Engineer, as appropriate. Prior to beam operation an Accelerator Readiness Review is conducted in accordance with DOE O 420.2.

<u>ALARA Committee</u>

Conducts reviews of initial equipment designs to ensure ALARA issues are considered, as well as the conduct of operations that have a direct impact on activation and dose reduction. The Committee documents are contained in RHIC OPMs 5.3.3.0, 9.2, 9.3, 9.4, 9.5, 9.6 and 9.7.

<u>Radiation Safety Committee</u>

Develops guidelines for safety specifications, reviews new or modified facilities or modes of operation for beam line safety, recommends the means and procedures to maintain beam line safety envelopes, and reviews the PASS design specifications and test procedures. The Committee documents are contained in RHIC OPM 5.0.2.3 and AGS OPM Chapter 9.

<u>Experiment Safety Committee</u>

Reviews conventional aspects of the design and construction of experimental facilities and systems. They act as a consultant in the design of safety systems and review experimental system Operating Procedures. The Committee documents are contained in RHIC OPMs 5.1.3.5 and 9.16.

<u>Accelerator Systems Safety Committee</u>

Reviews conventional aspects of the design and construction of the accelerator and beam line systems for compliance with ES&H. Review of engineering changes and modifications to the State Tables for the RHIC portion of the Particle Accelerator Safety System that do not deviate from the

System Specifications or the conceptual design for oxygen deficiency monitoring. The Committee documents are contained in and RHIC OPMs 5.0.2.1 and 9.1.

<u>Working Hot Oversight Committee</u>

Reviews the qualifications of personnel to perform Hot Work and issues Hot Work Permits. The Committee document is contained in RHIC OPM 5.0.2.2.

<u>ES&H Committee</u>

Conducts routine safety inspections of RHIC buildings, work areas and construction activities to ensure that unsafe conditions are identified and corrected. The ES&H Coordinator chairs the Committee.

RHIC Detector Operations

The construction of the RHIC detectors is conducted in accordance with the requirements of the RHIC OPM, the RHIC QA Manual, and the BNL ES&H Manual. The RHIC Experiment Safety Committee (ESC) carried out safety reviews of the large detectors, STAR and PHENIX on a subsystem-by-subsystem basis culminating with integrated detector safety systems reviews. The two small experiments, BRAHMS and PHOBOS were also reviewed by the ESC. These reviews are documented by meeting minutes as well as action items that are tracked in a database.

The ESC recommends installation of completed subsystems to the RHIC Project Director upon closure of action items and approval of relevant installation procedures. The RHIC Project Director then authorizes installation in the Assembly Buildings or Interaction Regions depending on the specific detector.

Safety analyses for the large experiments are included in this SAD. These are reviewed by the BNL ES&H Committee in accordance with BNL ES&H Standard 1.3.3. Modification of these facilities that require re-analysis and/or changes to the Accelerator Safety envelope, are first reviewed and approved by the RHIC ESC and then forwarded to the BNL ES&H Committee for review. Recommendations of the BNL ES&H Committee are sent to the BNL Deputy Director for Operations for approval of the SAD (including the Accelerator Safety Envelope). The Accelerator Safety Envelope must also be approved by DOE.

As required by ES&H Standard 1.3.2, installed subsystems are subjected to an independent review by the Laboratory Operational Readiness Review Committee. Two categories of action items are generated and tracked to closure: Pre-start or Critical action items, and Post-start action items. Permission to operate a given subsystem is issued by the RHIC Project Director upon closure of the Pre-start items.

Personnel access control to the detector Interaction Regions and sweeps for beam operations, under the PASS system, are reviewed and approved by the AGS/RHIC Radiation Safety Committee.

Finally, authorization to start commissioning the detectors with beam in the respective Interaction Regions is given by DOE-BHG after the Accelerator Safety Envelope has been approved by DOE and the Laboratory Accelerator Readiness Review report is provided.

The commissioning of the RHIC collider and detectors will be carried out under the responsibility and authority of the RHIC Project Director as per the memorandum in Appendix 50. The corresponding organization chart is shown in Figure 3-B-4.

Since the RHIC detectors are complex and are geographically isolated from the Main Control Room (MCR), the detectors will operate as self-contained satellites with MCR as the hub. As such, each detector will have an Experiment Commissioning Coordinator who acts as a liaison between the detectors and the accelerator personnel regarding status, running schedules and required maintenance.

The Detector Shift Leaders will assume first line responsibility for the safe operation of the detectors. They will operate under a set of procedures, approved by the ESC, that assure operation within the Accelerator Safety Envelope, adequate communications with the MCR Operations Coordinator, and appropriate response to any emergency that may arise. The RHIC Project Director approves the qualifications and appointments of the Detector Shift Leaders and their training is tracked by the Project. They are accountable to the RHIC Project Director and Associate Project Director for Experiments for construction, installation and commissioning; to the respective detector collaboration for detector maintenance, data flow and physics analyses; and to the MCR Operations Coordinator during beam operations.

When the accelerator is running with beam, the MCR Operations Coordinator is the focal point who is authorized to maintain or restore the accelerator and related experiments to operational status. The Operations Coordinator keeps current on the status of the experiments and in the event of incompatibility or conflict provides a resolution. For assistance in carrying out these duties, the Operations Coordinator consults with the Head of Operations and the Beam and Experiment Commissioning Coordinators regarding programmatic matters.

The detector Shift Leaders shall notify and obtain approval from MCR prior to introducing flammable gases into the detectors. MCR shall also be notified prior to energizing or shutting down major pieces of apparatus such as magnets and their power supplies.

The detector safety systems will be under configuration control. Requests for changes or bypass should be forwarded to Main Control and approval will be granted upon consultation with the cognizant Safety Committee Chair or designee.

B. RHIC BUILDINGS AND STRUCTURES

The conventional buildings and structures which comprise the Collider and support structures of the RHIC facility are described in this Chapter. RHIC utilities are each described in Appendix 12. The accelerator systems and experimental apparatus are described in their respective sections.

Portions of the RHIC conventional facilities, originally constructed for the former ISABELLE and CBA Projects, were left incomplete at the time of termination of ISABELLE/CBA in 1983. As part of the RHIC Project, unfinished conventional structures and systems were completed and, where necessary, elements of the facility have been brought into compliance with the applicable requirements of Federal, State and County orders, codes and regulations or, where appropriate, exceptions were obtained.

The original ISABELLE/CBA construction routed liquid effluents to cesspools and recharge basins. Some of this configuration did not comply with environmental regulations promulgated subsequent to ISABELLE/CBA. Remediation of the liquid effluent discharges is discussed in the section on environmental protection.

C. SITE ENVIRONMENTAL CHARACTERISTICS, ENVIRONMENTAL COMPLIANCE, AND MONITORING

C.1. Characteristics

The RHIC Project contributes to the overall mission of BNL, which is a multidisciplinary scientific research center located close to the geographical center of Suffolk County on Long Island, about 60 miles east of New York City.

The Laboratory site consists of 8.2 square miles, most of which is wooded, except for a developed area of about 2.5 square miles. The site terrain is gently rolling, with elevations varying between 120 and 140 ft. above mean sea level. The site lies within the western rim of the shallow Peconic River water shed. The RHIC site is located within the northern fringe of the developed site. Marshy areas and vernal pools located within the northern half of the RHIC ring are evidence of the Peconic headwaters. A flow channel enters the ring from the west at the 10 o'clock position and exits at the 2 o'clock. Culverts necessary for passage of water through the RHIC are provided under the Collider tunnel and Ring Road at both these locations.

In terms of meteorology, the Laboratory can be characterized, like most eastern seaboard areas, as a well-ventilated site. The prevailing ground level winds are from the southwest during the summer, from the northwest during the winter, and about equally from these two directions during the spring and fall.

C.2. Compliance

To comply with the requirements of the National Environmental Policy Act, prior to the start of construction of RHIC, an Environmental Assessment (EA) was composed and subsequently approved by DOE. After approval of the EA, a Finding of No Significant Impact (FONSI) was issued by DOE. The EA and FONSI are shown in Appendix 9.

Sanitary and process wastes generated by the RHIC facilities are regulated by State wastewater regulations. Currently sanitary wastewaters generated at facilities located at 5, 6 and 8 o'clock are discharged to the BNL sanitary sewer that is a state permitted discharge. Similarly cooling tower releases from these facilities are discharged to groundwater recharge structures. However, sanitary wastes generated at other facilities are discharged to subsurface wastewater disposal systems (i.e., cesspools, leach fields, drywells). These discharges may also be interconnected to facility floor drains. Plans are underway to connect these facilities to the sanitary sewer system, consequently relinquishing the need for the subsurface disposal systems. These connections should be completed by 2001. In the interim, all subsurface disposal systems have been included in the Laboratory inventory of Class V injections wells on file with the EPA. In addition, the NYSDEC has been apprised of these discharges and the current plans to connect these facilities to the sanitary sewer.

C.3. Cooling Water Releases

Cooling towers are located at the 2, 4, 5, 6, 8, and 10 o'clock positions. These systems provided secondary cooling to experimental or mechanical equipment used to support either RHIC operations or experiments. Cooling tower blowdown from the towers located at 5, 6, and 8 o'clock is currently permitted for discharge to SPDES Outfall 002. Discharges from 2, 4, and 10 o'clock are currently under review. A SPDES permit modification will be issued prior to Routine Operation of these facilities. To reduce the environmental impacts due to discharges of cooling water treatment reagents, innovative technologies are being applied at BRAHMS and PHOBOS, which eliminate the need for treatment chemicals. If successful, deployment of this technology will be extended to all secondary water systems in the complex. If not successful, use of water treatment chemicals will have to be employed. This action will be covered by the aforementioned SPDES Permit.

Primary cooling water for the experimental facilities is provided in most instances by recirculated deionized water systems. Unlike other accelerator systems presently in operation, the low number of the particle interactions with these cooling systems is not expected to cause activation of cooling water components. Accidental releases of this cooling media are therefore benign.

C.4. Oil Storage/Releases

Oil is found in all facilities in the form of working fluids for hydraulic or mechanical equipment. The volume of oil in these facilities is typically small. Vacuum pumps, hydraulic lifts are two examples of oil use. The Injection Kicker power supplied in Buildings 1005E and 1007W both use approximately 30 gallons of transformer oil each and the area around them is diked. At 5 o'clock however, significant oil volumes are associated with the cryogenic refrigeration system. While all mechanical equipment is located on impermeable surfaces (i.e., concrete) releases from these systems due to failed equipment have occurred. These releases have been minimized by rapid spill response actions by both the facility operators and the implementation of on-site spill response procedures. Further assessments of mitigative measures, will be conducted if modification takes place to the facility infrastructure, Collider, or Experiments.

C.5. Monitoring

a. Prior to Routine Operations of the Collider, a site baseline environmental radiation monitoring study was initiated in September of 1997. An array of six locations was deployed around the Collider, and a seventh monitoring point was positioned in Building 902 as a control.

b. Routine collection of Peconic River headwaters in the vicinity of the Collider beam stops has commenced.

c. Ground water monitoring wells near the Collider beam stops and collimators has commenced. Routine sampling shall commence as soon as possible thereafter.

d. Routine sampling of the recharge basin in Outfall 002 is already ongoing. This basin will be the discharge point for all cooling water blowdown in FY 2000. The New York State DEC has permitted local discharge of cooling water from the BRAHMS and PHOBOS experiments and the RF System to cesspool or surface points until the scheduled aforementioned storm water and sanitary system upgrade is complete.

D. HAZARD CLASSIFICATION AND DESIGN CRITERIA FOR PROMPT RADIATION

D.1. Hazard Classification

The Program Secretarial Officer for the Office of Science designated RHIC as a "Low Hazard" facility (Appendix 26). The design basis of the Collider and experimental systems represent minimal onsite and negligible offsite consequence.

D.2. Basis for Design Criteria for Prompt Radiation

Design criteria for prompt radiation and Design Basis Accident (DBA) fault in the Collider (described fully in Appendix 1) have been based upon the Beam Loss Scenario shown in Appendix 8. The criteria were established only for use by designers. Health physics controls, during operation, will be in accordance with the BNL Radiation Protection Plan as required by 10 CFR 835. The Risk

Category of the design criteria for prompt radiation is in conformance with BNL ES&H Standard 1.3.3., "Safety Analysis Reports/Safety Assessment Documents." An exposure up to the 160 mrem limit falls within Hazard Severity Category IV in the Hazard (or Risk) Matrix which appears as Figure 1 of that Standard. The Category IV Hazard Severity definitions are shown below. The Risk associated with any Category IV hazard, regardless of hazard probability, is defined as Routine. Review requirements for a Routine Risk also are provided below. Appendix 13 provides the documentation of the review of the Design Criteria, detailed in Appendix 1, by the DOE Independent Safety Review, the documentation of the concurrence by the BNL Safety and Environmental Protection (SEPD) Division Head and ES&H staff with respect to 10 CFR 835. Note: The SEPD was subsequently reorganized.

TABLE 3-D-1

BNL Category IV Hazard Severity Definition

Personnel Illness/Injury	Radiation Release/Exposure (Onsite/Offsite)	Public Impact Perceptions
Minor Injury or Minor Occupational Illness	Any radiation exposure to a radiation worker exceeding BNL's administration action levels	Negligible on overall BNL/DOE mission; minor on a sub-program

TABLE 3-D-2

BNL Routine Risk Requirements

Risk Category	Documentation Required	Minimum Approval Required
Routine Risk	Departmental and/or S&H Services Division Design Review	S&H Services Division

D.3. Controlled and Uncontrolled Area Classifications

Four area classifications are defined where personnel are allowed without restriction by physical barriers. The classifications are for use only by designers. Operational area classifications will be in accordance with the BNL RadCon Manual. These areas are categorized according to whether or not personnel allowed access have been trained as radiation workers (areas posted as Controlled) and according to whether the occupancy is expected to be "high" (i.e., continuous as defined by 2000 h per year) or "low," defined as a region with an occupancy factor (OF) of 1/16 (½ h per 8 h day) or below. Regions with intermediate occupancy will be treated as if they are high occupancy areas.

a. Area "A": Radiation workers; high occupancy. This is typical for experimental counting houses. If assembly areas adjacent to Experimental Halls are required to have significant occupancy while the beam is on, these would also fall into this classification.

b. Area "B": Radiation workers; low occupancy (1/16 of or below). This area is typified by the possible need to have movable shielding inside an Experimental Hall where occasional access would be required for work on fast electronics modules close to detectors.

c. Area "C": Non-radiation workers; high occupancy. The occupants in this area are considered as members of the general public, with occupancy greater than 1/16. The Collider center is an archetype.

d. Area "D": Non-radiation workers; low occupancy (1/16 OF or below). This classification is intended to represent (most of) the regions which physically connect the Collider center to the remainder of the site and are used for transient access--roadways, parking lots, etc., and most of the berm over the Collider.

D.4. <u>Design Criteria</u>

Design criteria for dose limits for the areas described in the preceding section are shown below. Both normal loss limitations and DBA fault limitations are considered. The annual dose fault limitation is applied to both the transfer line and the Collider.

a. Classification "A": Radiation workers; high occupancy.

   1. *Normal loss* - 0.2 mrem/hr
   2. *DBA fault* - 500 mrem/yr limit

b. Classification "B": Radiation workers; low occupancy.

1. *Normal loss* - 3.2 mrem/hr

2. *DBA fault* - 1000 mrem/yr limit

c. Classification "C": Non-radiation workers; high occupancy.

1. *Normal loss* - 15 mrem/yr

2. *DBA fault* - 10 mrem/yr limit

d. Classification "D": Non-radiation workers; low occupancy.

1. *Normal loss* - 240 mrem/yr

2. *DBA fault* - 160 mrem/yr limit

E. TRANSFER LINE - U-, W-, X- AND Y-LINES

Beam bunches extracted from the AGS pass through a Transfer Line to get from AGS to the Collider, a layout of which appears as Figure 3-E-1. The Transfer Line is also called the AtR (AGS to RHIC) line, and begins downstream of AGS extraction which comprises a new G-10 Extraction Kicker and new H-10 Extraction Septum. Before exiting the AGS, the beam undergoes a 4.25^{o} bend through two dipole magnets accompanied by three quadrupoles. The bunches then traverse a spur called the U-Line, which had been in operation for many years for the AGS neutrino program. The old U-Line has been dismantled, and all components have been either re-furbished or replaced for AtR operation.

An 8^{o} dispersion free bend comprised of four gradient dipoles connected in a modified triplet configuration is found in the U-Line. Prior to the 8° bend, a stripping station is located where the last two electrons are removed from the as yet not fully stripped heaviest species. The stripper can be retracted when it is not needed. Transport optics are designed to form a double waist at the foil to minimize the dilution in phase space of the beam caused by scattering in the foil and to compensate for the associated changes in emittance shape. This first section of the AtR will be shared during the first years of operation with the g-2 AGS experiment. Optics components were chosen to accommodate the differing transport requirements. A pair of g-2 deflection magnets (VD3 and VD4) are located just upstream of the 8^{o} bend. Activation of the deflection magnet pair will direct beams to the g-2 target for the AGS experimental program; deactivation allows RHIC injection. Six quadrupoles preceding and four following the 8^o bend allow tuning capability to prepare the bunches for acceptance into the subsequent W-Line spur.

This next section of the beam Transfer Line, the W-Line, deflects the beam both horizontally and vertically, such that its axis at the entrance to the ring selector runs along the intersection of a horizontal plane, approximately 48 mm above RHIC's median plane, and the vertical plane through the machine center and the crossing point at 6 o'clock.

The horizontal deflection in this section is 20^o in an arc with an average radius of 405.82 m, the change in vertical level is approximately 1.73 m. The horizontal deflection and the change in level are entwined: the former is performed by a string of 8 gradient magnets in an alternating gradient focusing arrangement, the latter by a pair of vertical pitching dipoles, the first one of which is located between the second and third horizontal deflectors. The gradient magnets are each about 3.66 m long with a field strength of about 1.19 T. They are separated from each other by drift spaces of 14.05 m. The second pitching dipole is placed between the second and third quadrupole of a string of six between the last horizontal deflector and the switching magnet (ring selector). These, together with the upstream quadrupoles in the U-Line, provide for flexibility in the choice of focusing parameters at the entrance of the ring selector. With the switching magnet de-energized, the beam will stop in a marble encased steel beam stop at the end of the W-Line.

F. COLLIDER TUNNEL ENCLOSURE

General Description

The circumference of the RHIC enclosure approximates 2.4 miles, including the experimental areas. The Collider Tunnel is approximately 1.9 miles of this circumference. The cross sectional shape of the tunnel is a modified horseshoe fabricated from steel multiplate arch. At locations on either side of the experimental areas, the enclosure is enlarged in diameter to accommodate ancillary experimental apparatus. Since there are a total of six experimental areas, the Collider Ring can best be described as being made up of six sextants, each essentially identical to the others, except the reinforced concrete areas adjacent to the 6 o'clock position, and one near the 4 o'clock location. In each of the six sextants there are three equipment/emergency exit alcoves, one located in the center and two approximately 388 ft on each side. In addition to providing egress these alcoves house machine power supplies, instrumentation, controls and electrical distribution panels.

Six areas, 2, 4, 6, 8, 10 and 12 o'clock, have been provided with the major structures necessary to operate experiments. The gaps at 10 and 12 o'clock which were left uncompleted when ISABELLE/CBA was terminated have been closed as part of the conventional construction. Multi-plate arch tunnels 16 ft and 26 ft in diameter were erected at 10 o'clock, along with a Service Building. At 12 o'clock, 16 and 26 ft diameter multi-plate arch tunnels were erected, along with 2 concrete headwalls, 2 stair structures, a base slab and Service Building. Corrugated pipe magnet access tunnels were constructed at either side of the 8 and 12 o'clock regions. The 12 o'clock area is staged for development, thus maintaining the option of adding an Experimental Hall in the future. Furthermore, the area has been constructed so that machine operations can continue during construction on the Experimental Hall, should the area be developed. Currently, the region has been enclosed with concrete block shielding.

The area and height of the Experimental Halls at 2, 6, 8 and 10 o'clock vary (see Table 3-F-1 for their dimensions, crane capacities and beam heights). Each location is equipped with overhead cranes, air conditioning, sprinkler protection and has direct access from grade. Note that 10 o’clock is not equipped with an overhead crane. The Open Area at 4 o'clock has a concrete deck capable of supporting block shielding in varying configurations. The 6 and 8 o'clock Facilities have each been provided with an Assembly Building.

In order to house main magnet power supplies, instrumentation and cryogenic valve boxes, additional Support Buildings were constructed at the 2, 4, 6 and 8 o'clock locations. The RF Power Supply Building, which will contain power supplies and other associated equipment, will be located adjacent to the 4 o’clock Service Building. The PHENIX Counting House is situated between the 8 o’clock Assembly Building and the Service Building. Dimensions of all the Support and Service Buildings are given in Table 3-F-2.

TABLE 3-F-1

Summary of Hall Dimensions

Location	Building	Elevation	Length	Width	Beam Height	Hook Height/ Capacity (ft/tons)
2	Narrow Angle					
	Central Hall	63'6"	91'	42'	5'8"	20/20
	Expanded Tunnel Section	63'6"	248'	26'	5'8"	
	Spectrometer Tunnel	66'2"	326'	8'	3'0"	
4	Open Area	62'0"	188'†	96'†	7'2"	
6	Wide Angle					
	Central Hall	55'	105'	53'	14'2"	36/40
	Assembly Building	55'	132'	61'	14'2"	40/40+40/10
8	Major Facility					
	Central Hall	52'	61'	57'	17'2"	36/40+35/10
	Assembly Building	52'	61'	61'	17'2"	36/40+35/10
10	Major Facility	65'	200'	26'	4'2"	
12	Major Facility (Future)					
	Central Hall	52'	55'	76'		
	Expanded Tunnel Section	65'	70'	26'	4'2"	

†Pad dimensions given

TABLE 3-F-2

Summary of Building Dimensions

Location	Building	Length (ft)	Width (ft)	Building No.
2	Service Support	48 80	58 40	1002A 1002B
4	Service Support RF Power Supply Bldg.	48 120 81	32 40 40	1004A 1004B 1004A
6	Service Support	48 80	58 40	1006A 1006B
8	Service Support PHENIX Counting House	48 80 107	58 40 52	1008A 1008B 1008A
10	Service	52	89	1010A
12	Service	52	89	1012A

The floor elevation for the magnet enclosure was established at 65 ft above sea level to optimize the earth-work requirements for shielding. The majority of the Collider enclosure is covered by a minimum of 13 ft of sand. It is provided with emergency ventilation, humidity control, potable and fire protection water, compressed air, normal and emergency electric power and lighting, fire alarms, communications and a Particle Accelerator Safety System (PASS).

The magnets and support mechanisms are located along the centerline of the enclosure which allows service and access on either side of the magnets. Cable trays that bring power, control and other machine related wiring are located over the magnets and away from the aisles. The utility piping, wiring and duct work is located on the periphery of the steel arch, with most of these above the 8 foot level to allow as much free space as possible for servicing the machine components. The typical tunnel cross-section is shown in Figure 3-F-1.

G. COLLIDER CENTER

The Collider Center (Building 1005S) is a four story structure of 45,700 ft^2 located just inside the ring at the 5 o'clock position. It is steel framed with insulated metal siding and air conditioning. It contains shops, offices and the Main Control Room. The RF building, described elsewhere, is a high bay attached to the Collider Center, on the east side. The cryogenic refrigerator buildings are on the west side.

The third floor contains control and computer electronics for the accelerator. There is a pre-action sprinkler system and combination fixed temperature/rate-of-rise fire detectors. There is a floor with removable panels. The other three floors in the building contain typical office furniture, equipment and supplies. These areas are protected with a wet pipe sprinkler system. Fire protection is fully described in Chapter 4.I.

H. NARROW ANGLE HALL AT 2 O'CLOCK

The Brahms Detector is located in the Narrow Angle Hall (NAH) which consists of a central Experimental Hall, expanded tunnel sections, and a spectrometer tunnel. Section V describes the Safety Analysis for small experiments.

The Experimental Hall is constructed of reinforced concrete. It is 91 ft long, 42 ft wide and 28 ft high with a 20 ton overhead crane. The outer ring wall is banked with earth to the roof-line, while the inner ring wall is a metal skin with access doors. The front wall is enclosed with removable concrete block shielding.

The expanded tunnel section is constructed of a reinforced concrete slab with a 26 foot diameter multiplate steel arch in the counterclockwise direction and the expanded section which is 222 ft in the clockwise direction from the research hall and contains the accessway to the Support Building. A schematic of the NAH is shown in Figure 3-H-1. The Spectrometer Tunnel is an 8 ft diameter ×326 ft long tunnel extending clockwise from the expanded tunnel section and tangent to the RHIC ring. The outer end of the tunnel is enclosed with concrete block shielding, and the inner side was closed with a masonry wall and steel door.

I. OPEN AREA AT 4 O'CLOCK

This is an open (uncovered) reinforced concrete slab 188 ft long and 96 ft wide. The beams cross at the center of the pad. Concrete block shielding is provided to enclose this area. Some of the RF cavities are located in this area along with the possibility of future development of a small detector. A schematic of the Open Area is shown in Figure 3-I-1.

J. WIDE ANGLE HALL AT 6 O'CLOCK

The STAR detector facility is located in the Wide Angle Hall (WAH) in the 6 o'clock position that consists of a reinforced concrete hall 53 ft long, 105 ft wide and 40 ft high with a 20 ton overhead crane. It is banked with earth to the roof line on three sides. Concrete block shielding is provided on the inner ring side of the experiment to permit the detector to be rolled out of the Collider for servicing. The crossing point is at the center of this hall 14 ft 2 in. above floor level. Adjacent to the Wide Angle is a 9790 ft^2 assembly building. A schematic of the structure at 6 o'clock is shown in Figure 3-J-1. The STAR detector is described in Section 3.T and 4.N.

K. MAJOR FACILITY HALL AT 8 O'CLOCK

The PHENIX detector is located in the Major Facility Hall (MFH) that consists of a central hall and two expanded tunnel areas. Adjacent to the MFH is a 3700 ft^2 assembly building and a counting house and rack room. Concrete block shielding is provided between the MFH and the assembly building. The central hall is 57 ft long by 61 ft wide and 47 ft high with a 40 ton overhead crane. The same 40 ton crane, plus a 12 ton crane (not yet installed) cover the Assembly Area. The expanded concrete tunnel areas on either side of the Central Hall is 53 ft long by 30 ft wide and 21.5 ft high with a 9'6" concrete platform to raise the floor level. The Assembly Hall is steel frame with metal siding. A schematic of the structures at 8 o'clock is shown in Figure 3-K-1. The PHENIX detector is described in Section 3.U and 4.O.

L. MAJOR FACILITY HALL AT 10 O'CLOCK

The PHOBOS Detector is located in this area which consists of a 26 ft diameter multiplate arch enclosure and a 2 ft 8 in. thick concrete slab. Overall dimensions are 26 ft wide×300 ft long. Connected to the facility via a utility tunnel is a Service Building measuring 88 ft×50 ft. A schematic diagram of the hall is shown in Figure 3-L-1. Section V describes the Safety Analysis for small experiments.

M. MAJOR FACILITY HALL AT 12 O'CLOCK

This area has been staged for future development of a large detector. A reinforced concrete pad 200×59 ft has been built to facilitate construction of a future Experimental Hall without interruption of Collider operations. The gap between sextants was closed with concrete shield blocks leaving a corridor for personnel and Collider utilities to pass through. A Service Building measuring 88×50 ft is adjacent to the Collider Tunnel. A schematic of the area is shown in Figure 3-M-1.

N. COLLIDER SUPPORT AND SERVICE BUILDINGS

The Service Buildings at 10 and 12 o'clock are one story metal skinned structural steel column and steel beam structures 88 ft by 50 ft in plan and 21 ft high. Each structure has an 1100 ft^2 mezzanine, air conditioned 550 ft^2 Control Room and a toilet. The building is supplied with standard heating, ventilation and electrical systems and has sprinkler protection and fire detection.

The Service Buildings at 2, 4, 6 and 8 o'clock are structural steel column and steel beam structures ranging in size from 1500 ft^2 at 4 o'clock to 2800 ft^2 at the three others. Each building has a mezzanine and a toilet and is air conditioned.

The Support Buildings at 2, 4, 6 and 8 o'clock are pre-engineered 25 foot high steel structures ranging in size from 3200 ft^2 at 2, 6 and 8 o'clock to 4800 ft^2 at 4 o'clock. Each building has an air conditioned Control Room and normal heating ventilation and electrical systems. The 4 o'clock building has sprinkler protection.

O. PARTICLE ACCELERATOR SAFETY SYSTEM (PASS)

O.1. Overview

Personnel will be protected against radiation hazards, oxygen deficiency hazards (ODH), and electrical hazards by an integrated personnel safety system. Ensuring personnel safety at older accelerators meant an access control system designed to protect personnel only from radiation hazards. Other safety hazards to be found within accelerator enclosures or Support Buildings were mitigated by their own independent administrative controls or engineered safety solutions, often after the initial accelerator design phase and independent of the access control system design. Integration all personnel safety systems in RHIC is expected to result in a superior level of personnel safety and equipment protection, while providing greater operational efficiency. It is also intended that the PASS will have a closer interface to the fire protection elements installed as part of our conventional construction than has been the case in other accelerator construction.

O.2. Personnel Safety Systems

Required safety systems for Oxygen Deficiency Hazards (ODH), Electrical Hazards and Radiation Hazards are integrated into a single system. The Personnel Safety System will employ fourteen small Programmable Logic Controllers (PLC) interconnected as two sets of seven peers, Divisions A and B in Figure 3-O-1, rather than a few larger units hierarchically connected to multiple remote I/O chassis. This is done to achieve a redundancy level, for the most complex part of the system, greater than that provided by the dual level achieved by other designs.

The design and configuration of hardware for this system were reviewed by an invited external committee, conducted on March 7-9, 1995. The Committee included personnel safety systems experts from Fermilab, CEBAF, ALS and NSLS. Both CEBAF and ALS use PLC-based personnel safety systems. The Committee report, Project response and the approval of the response are included as Appendix 14. All but two of the Committee recommendations were accepted by the Project. The two recommendations not accepted concerned philosophical differences of opinion over reliability and not system safety. Subsequent to the external committee review, the Directorate appointed an ad hoc subcommittee to review the PASS System as required by ES&H Standard 1.5.3. The subcommittee found the design to be in compliance with all requirements and made four recommendations that were guidelines for improvements.

a. Control Devices

Commercially available Programmable Controllers are configured so as to attain the level of redundancy necessary to achieve compliance with DOE 5480.25. A network of PLC units compensates for the complex set of failure mechanisms exhibited by individual processors as compared to designs based upon relays, much as a OP-Amp compensates for component variability with gain and feedback or a bridge is supported by its interconnecting I-beams. In order to reduce the potential for common mode failures, the core PLC system will be comprised of two different models of PLCs such that basic hardware and software elements will be of different architecture; each PLC has its own independent UPS and line power feed. Complications introduced by physical bus limitations result in a rather complex interconnection pattern, however, a minimum of two independent Divisions labeled A and B are always maintained. The A and B Divisions are in turn connected to one of two command and control processors which provide supervisory control and monitoring functions. These processors are in their turn redundantly connected to the RHIC Central Control System and to a Personnel Safety System generated Display located in the RHIC Central Control Room.

b. Safety Devices

An emergency shutdown system labeled CRASH will use "pull cord" type switches. They will be installed throughout the W-, X-, and Y-Lines, Experimental Halls and the Collider Tunnel. In some areas of the detector halls, crash buttons will be deployed where crash cords are not practical. For most of the enclosures, there will be continuous coverage. Typically, each unit will protect 200 ft of tunnel. The CRASH switches are double pole and not hard wired into the system, but are redundantly connected to the A and B Divisions. When a CRASH is requested, the system will remove power from the corresponding critical device. Concurrently, a signal will be sent to activate the Beam Stop. Note, the Beam Stop is not defined as a critical device and therefore not a safety grade component, nor is it considered as part of PASS. During a crash initiation, the Beam Stop is used for machine component protection. If the Beam Stop fails, vacuum valves are used as critical devices to dispose of stored beam.

The Collider Enclosure Gate System comprises thirty five (35) Gate packages and nineteen (19) Emergency Entrance and/or Exit Doors packages. An additional nine (9) gates are employed for the Transfer Line. Redundant switches are mounted on each of these doors. Entrances to the Collider will have a set of captive keys interfaced into the PLC logic such that if any key is missing from the key bank, then the Collider and injection cannot be started. At the gates there will also be a standardized status indicators. This package will include TV monitoring display in the MCR. Provision will be made to upgrade the Main Gate with a card reader based entry logging system and information display.

The radiation area monitoring system will employ the Chipmunk design used extensively at the AGS, NSLS and Fermilab. Interlock outputs are connected to system PLC units.

c. <u>Distribution</u>

The PLCs are wired and programmed so that each will independently supervise the interaction area and the sextant areas nearest their physical location. In simple terms, they provide coverage both clockwise and counterclockwise for the half-sextants nearest the Intersection Region. Sensor and control elements within the tunnel enclosure will operate at 12 or 24 Vdc (gate switches, ODH alarms, etc.). Distribution boxes located approximately every 65 m (200 ft) will be interconnected via dual multi-drop supervised cables to the PLC units, as will the wiring for Gate and Emergency Entrance/Exit Doors.

Redundant signals are carried via separate cables except when a conduit is used; safety system cables are carried either in their own tray or via conduit.

P. INJECTION SYSTEM

A schematic of the Transfer Line is shown in Fig. 3-P-1. It begins downstream of the AGS H-10 fast extraction system which previously operated for the bubble chamber and neutrino physics programs in the U-Line. The H-10 fast extraction system has been recommissioned and now services the RHIC injection via the U-Line and the AGS experimental program in the V-Line. Safety reviews of the Fast Extraction System and the V-Line are promulgated in AGS safety documentation. For operational and safety reasons, the U- and V-Lines are not designed to operate concurrently in pulse to pulse modulation. This means that a system of hardware and administrative controls have been established to distinctly separate U- and V-Line operations. The U-Line includes collimators, a stripping station, where the last two electrons are removed from the as yet not fully stripped heaviest ion species, and beam position instrumentation. The U-Line leads to the W-Line, which ends in a switching magnet. The switching magnet diverts the beam into either the, X or Y-Line, which lead to the Collider tunnel clockwise in the Blue Ring and counter-clockwise in the Yellow Ring, respectively. If the switching magnet is turned off, the beam in the W-Line ends up on the zero degree beam stop. This beamstop was located in the X-Y crotch for the purpose of studies and setup.

Since this is an intended loss point, additional shielding has been provided above it. The existing fence on the U-Line has been extended to enclose the entire W-Line and zero degree beamstop.

All the beamline hardware in the Transfer Line consists of conventional magnets and instrumentation commonly found throughout the AGS complex.

Q. CRYOGENIC SYSTEM

Q.1. General

Refrigeration to provide 4 Kelvin supercritical helium gas required for RHIC will be produced by the 25 kW Helium Refrigerator. The refrigerator is housed in two structures that are part of the Collider Center Complex. The helium is distributed by means of piping and valve boxes, both of which are vacuum jacketed, plus ancillary warm piping and valves. This system carries the helium to and from the Cryogenic Building, passing out-of-doors into the valve boxes located at 6 o'clock, which are the primary interface points to the superconducting magnets. The cryogenic loop continues through the magnets and the five remaining Service Buildings located near the Experimental Areas around the Collider. A description of the technical parameters of the Cryogenic System may be found in the RHIC Design Manual. An inventory of cryogenic gases, by location in each building, is shown in Table 3-Q-1. None of the experimenters have expressed an intent to use cryogens from the helium refrigerator.

The Cryogenic Building (1005R) is a high bay, steel framed, masonry construction building approximately 7,200 ft^2 in area, with a volume of about 240,000 cubic feet, and is located immediately west of, and contiguous to, the Collider Center (Building 1005S). Though contiguous, the two buildings are structurally separate to insure acceptable acoustic levels in the Collider Center. The Cryogenic Building includes an 18-foot by 50-foot truck service platform. Access is through a 12-foot roll-up door and five man-doors.

The exterior of the building is comprised of concrete block with five, approximately 16 foot square, openings on the north side through which the Cold Boxes were installed. These openings were then sealed to the vacuum tanks of the Cold Boxes.

The Compressor Building (1005H) is a one story, high bay, similar in construction to the Cryogenic Building. It is approximately 10,800 ft^2 in floor area with a volume of about 200,000 cubic

TABLE 3-Q-1

Helium Inventory by Location
(×1000 SCF)

Volume of Vessel	Location	Inventory During Shutdown	Machine Inventory Normal Operation
	OUT-OF-DOORS		
8	Compressor Buffer Tanks	8.0	36
160	RHIC Gas Storage	2693.0	787
1	Outdoor VacJac Piping	1.0	452
4	30,000 gal LHe Storage	2,840.0	459
		5,542	1734
	COMPRESSOR BUILDING		
4	Compressor System	4	48
		4	48
	REFRIGERATOR BUILDING		
.2	Cold Box #1	.24	5
.2	Cold Box #2	.24	1
.2	Cold Box #3	.24	12
.2	Cold Box #4	.24	80
.2	Cold Box #5	.24	464
.2	Other	.24	75
		1.44	637
	TUNNEL		
.9	Sextant 1	1.0	663.5
.9	Sextant 3	1.0	663.5
.9	Sextant 5	1.0	663.5
.9	Sestant 7	1.0	663.5
.9	Sextant 9	1.0	663.5
.9	Sextant 11	1.0	663.5
		6.0	3981.0
	SERVICE BUILDINGS		
1.7	2 o'clock	2	50
1.7	4 o'clock	2	50
1.7	6 o'clock	2	50
1.7	8 o'clock	2	50
1.7	10 o'clock	2	50
1.7	12 o'clock	2	50
		12	300
	SUM OF ALL ABOVE	5,565.44	6700

feet. It houses the helium compressors and their associated equipment. It is located just to the northwest of the Cryogenic Building.

The six Service Buildings are metal frame, pre-engineered structures. The volume of these buildings varies from 70,000 to 113,000 cubic feet. Two (one for each ring) Valve Boxes are located in each Service Building. In addition, the Main Ring magnet power supplies are located in these buildings with their ancillary equipment. The 6 o'clock Service Building (1006B) is also the location for a 300 Watt Helium Refrigerator which, typically, will operate as part of the helium recovery system only when the main 25 kW Helium Refrigerator is shutdown.

The Refrigerator and Compressor Buildings and the equipment located in them were reviewed by the Laboratory Cryogenic Safety Committee before the equipment was operated for acceptance tests. An addendum describing the changes made in the refrigerator to prepare it for use in RHIC was written in 1994. Both the Safety Analysis Report submitted for the 1984 review and the 1994 addendum are found in Appendix 2.

Q.2. Compressor Building -- 1005H

The compressor building houses the mechanical equipment which compresses the helium for the Helium Refrigerator. One of the hazards in this building is the very high ambient noise level when the compressors are in operation. The hazard extends outside the building in the vicinity of the large pipes to and from the refrigerator area. Warning signs for high noise levels are posted at the entries to the hazardous area. A noise survey was taken in this building during the Compressor Acceptance Test (April 10, 1985), see Appendix 3. This survey found a fairly uniform noise level of 110 dBA in the area of the compressors. According to the American Conference of Governmental Industrial Hygienists (ACGIH), repeated exposure in excess of 1.5 minutes duration to this noise level can cause hearing impairment. Therefore, hearing protection in this building is mandatory and occupancy time will be restricted to four hours of exposure per day. Employees with regular access to the building are included in the Laboratory Hearing Conservation Program.

Another hazard is the pressure piping which has a maximum working pressure of 275 psi. Pressure relief valves and rupture disks protect the system from exceeding this pressure. All major piping was analyzed to the requirements of ANSI B31.1, Power Piping requirements. The vessels are built in accordance with the ASME Pressure Vessel Code, Section VIII.

Interfaces between components and process piping are welded wherever possible. Flanged connections, where required, use "O"-ring seals. All piping subject to thermal cycling has been stress-analyzed. A detailed finite element analysis of pressure, dead weight, thermal and vibration stresses has been done with particular attention given to piping connected to the compressor casings. There is a helium capacity of 48,000 standard cubic feet of gas contained in the equipment in the building.

In the event of a release of helium, fixed oxygen deficiency monitors at ceiling level will alarm to indicate a low oxygen level (18%). The monitors report to the PASS System and, in addition, there are local audible alarms and visual strobe lights and annunciation of the alarms in the Cryogenic and Main Control Rooms. The building is also equipped with an automatic emergency ventilation system that activates on the low oxygen alarm.

The compressors are oil flooded, rotary screw compressors. The aggregate oil contained in all of the system is about 4400 gallons. This represents the major fuel load in the building. The oil, UCON-170X, has a relatively high flashpoint, 450°F, and is contained in closed metal sumps. The largest sump has a capacity of about 300 gallons. The cover gas over the oil in the sump is helium.

The building is equipped with a wet pipe sprinkler system. Fire detection is with smoke detectors in the electrical service room and the computer Control Room.

Electric systems involve 13.8 kV in the substation and 4160 VAC in the compressor motor power circuits. In addition, the normal power distribution system has circuits of 110, 220 and 460 VAC.

The power distribution has been installed in accordance with the National Electric Code and other codes which specify the equipment to be used and how it must be installed. All power cables are either fully insulated or fully enclosed to prevent personnel contact when systems are energized.

Q.3. Refrigerator Building -- 1005S

This building contains the 25 kW Helium Refrigerator which is the heart of the Cryogenic System. The refrigerator is comprised of heat exchangers, valves, piping, dual impurity adsorption equipment, turbo expanders and centrifugal compressors. This equipment has been divided into five separate cold boxes.

Most of the equipment that operates at low temperatures is housed within vacuum tanks or casings. A single exception is the low temperature piping interconnecting components of the refrigerator. The warmest sections of these lines, with a design condition from ambient temperature to 80 K are insulated with closed cell foam insulation with a vapor barrier. Below this temperature the lines are vacuum insulated.

The vacuum tanks are recognized as a Confined Space Hazard and RHIC OPM 8.1.3.16 addresses the requirements for entering that space.

The heat exchangers, interconnecting piping and valves are contained within cold boxes (vacuum tanks) 1 to 5. These tanks are partially housed within the Referigator Building at grade elevation (73 ft above MS). They are mounted in saddles and supported by concrete footings. One end of each tank projects through the wall into the building. Cold boxes 1 and 2 are the warm end of the refrigerator and are located to the west side of the building, nearest the Compressor Building. The cold boxes operate at progressively lower temperatures as one moves to the East, with Cold Box 5 housing the coldest components. A detailed description of the refrigeration cycle which is used by this plant can be found in the RHIC Design Manual.

This building, because of the large quantities of helium in the cold boxes, presents an Oxygen Deficiency Hazard (ODH) in the event of a catastrophic accident. In the event of a release of helium, fixed oxygen deficiency monitors located at ceiling height will indicate the oxygen level and alarms will be activated at a level of 18%. The monitors report to the PASS System, while local audible alarms and visual strobe lights are in the building. The building is also equipped with an automatic emergency ventilation system that activates on the low oxygen alarm. As shown in Chapter 4, the risk of fatality due to a helium release is higher in the refrigerator area and, therefore, the workers who enter must be specially trained and equipped with a five minute escape pack and a Personal Oxygen Monitor (POM). This is the only building on the site where such special training is required for access.

Because so much of the piping and other equipment are contained in vacuum jackets, a double failure is necessary to produce a significant release of helium in this building. Two 25,000 SCFM roof fans are used to remove any spilled helium from the building (See Appendix 2). The building make-up air intake is located along the south wall between the 75-foot and 83-foot elevations. At this location it is least likely to allow a recirculation of vented air/helium mixture.

The Cryogenic Control Room is located in the Collider Center, Building 1005-S. One section of the Control Room contains the process control computers. A description of the control system may be found in the RHIC Design Manual.

Q.4. <u>Service Buildings</u>

All Service Buildings will contain the same types of equipment, namely the power supplies for the Collider magnets and two cryogenic valve boxes with the piping to connect them to the ring. Each building has a different mix of power supplies and cryogenic equipment. The volume of air flow in the roof fan design for cooling and venting is chosen to meet the local requirements of each building.

Each building contains a computer room. This room is completely partitioned off by a 1 hour fire rated enclosure from the remainder of the building and is air conditioned with air drawn from outside the building. At the 10 and 12 o'clock positions these buildings also serve as Support Buildings and have a few other amenities such as a rest room and a janitor's closet. The conditions at each building are summarized in Table 3-Q-2.

Dual sensors, to detect an ODH condition in the Service or Support Buildings that house valve boxes, shall be operating when helium is present. The location of the sensors was chosen to be at the highest point of the sloped building ceiling. The outputs of the building monitors respond locally with audible alarms and warning lights, as well as back through the PASS System that controls access gates and emergency ventilation.

TABLE 3-Q-2

Service Building Parameters

	2:00	4:00	6:00	8:00	10:00	12:00
Building Number	1002B	1004B	1006B	1008B	1010A	1012A
Footprint Size - ft	40×80	40×120	40×80	40×80	50×88	50×88
No. Power Supplies	37	51	37	37	46	37
Total Power - MW	0.18	6.11	0.18	0.18	0.26	0.18
No. Valve Boxes	2	2	2	2	2	2
No. Personnel Exits	2	3	2	3	6	6
No. Fans	2	2	2	2	2	2
Total Fan Flow - SCFM	32,000	44,000	32,000	32,000	22,000	22,000
Special Hazards	ODH	ODH	ODH	ODH	ODH	ODH

Q.5. Equipment Design

A formal Quality Assurance (QA) Program is a requirement of the RHIC Project management (see Chapter 6). This program was followed throughout the design and construction stages of the Cryogenic System.

In addition to the review process required by the QA program and routine DOE Project Reviews, the Cryogenic System was the subject of two other significant reviews. In March 1992, an external committee, the *RHIC Cryogenic System Technical Review*, reviewed the conceptual design of the system. Their comments were factored into the design. The committee who conducted the *Independent Safety Review of RHIC* (December 2-3, 1992) also included the Cryogenic System in its deliberations.

The Collider Ring Division QA files contain the records of all conceptual and final design meetings and reports and all of the technical design specifications. Each cognizant engineer for a subsystem maintains a an engineering record book which contains the QA pertinent documents which he is required to store. The nature of these records is indicated in the "QA Record Index, RHIC Cryogenic System" which is Appendix 4.

The Cryogenic System was designed with due consideration to the appropriate inputs indicated in Table 1-A-1. Because of the nature of this system the mechanical design is most heavily influenced by the ASME Pressure Vessel Code, Section VIII and the ASME Refinery Piping Code, B31.3. Design, fabrication and testing was performed in accordance with these codes. Proprietary computer codes were used for stress calculations to aid design compliance with the codes. All stress calculations, typically part of the cognizant engineer's responsibility, have an independent engineering check as part of the Collider Ring Division QA program.

Where vessels or piping are to operate at cryogenic temperatures the material used is chosen to retain ductility at cryogenic temperatures.[8] Cracks or other flaws which might somehow be initiated do not propagate to catastrophic size because of the material ductility and because even a small leak is soon evident when the insulating vacuum fails and causes a large increase in the heat load, possibly resulting in an aborted run. The heat load would increase by a factor of about two when the vacuum spoils from 1×10^{-4} to 3×10^{-3} Torr.

Complete and accurate Process and Instrumentation Drawings (P&IDs) have been prepared for all cryogenic systems. The P&IDs which were part of the delivery from Koch Process Systems for the 25 kW Refrigerator and the Compressor System have been scanned for AutoCAD and are maintained along with the BNL generated P&IDs in the Collider Ring Division AutoCAD file system. These files contain 141 electrical P&IDs and 263 mechanical P&IDs. The Collider Ring Division Design Room which maintains the drawing files for the P&IDs also maintains an Active Components List for valves and other components. This list is used to control the component numbers used on the drawings and in the field for permanently mounted labels and tags. These records are part of the RHIC baseline and are changed only by means of Engineering Change Requests/Notices (ECR/ECN) which are part of the formal configuration control process for RHIC. No change (except in emergency situations) will be made in the equipment and piping shown on these drawings until an ECR/ECN has been issued approving said change. A "debriefing" session with the cryogenic Control Room personnel will follow operational periods to determine if changes may improve or simplify the capability of the system. These changes, if any, would be implemented by means of ECR/ECNs. Because the P&IDs are all electronic files on AutoCAD, it will be relatively easy to make any changes in a timely manner and, thus, keep these drawings up-to-date.

Q.6. Equipment Testing

All pressure vessels and pressure piping have been pressure checked in conformance with the relevant code requirements. Table 3-8 in the RHIC Design Manual gives the pressure ratings of the major subsystems. Because many of the vessels and piping have vacuum insulating systems, the maximum design working pressure in every case, where it is applicable, takes into account this extra loading. The heat exchangers in the refrigerator, pressure vessels in the Main Compressor System and some of the other seminal equipment have been hydrostatically tested to 150% of the design pressure. The other equipment has been pneumatically pressure tested to 125% of the design pressure. The piping has been pneumatically tested to 110% of the design pressure in accordance with ASME B31.3.

Some of the equipment; e.g., recoolers, have been functionally tested as prototypes. Others; e.g., cold compressors and valve boxes, have been tested at room temperature and liquid nitrogen temperature (80 K), but not at 4 K. Most of the distribution piping will not have been to cryogenic temperatures until it is installed in RHIC.

Q.7. <u>Operations</u>

Operations Procedures have been prepared for each required function of the Refrigerator and Compressor Systems. The RHIC Operations Procedures Manual (OPM) will also be used for training operators on the system. The OPM is available in a read-only format via computer network. The latest approved version can be obtained on-line by the Operator (or the reviewer). These files are maintained at the Project level. Checklists required for start up, shutdown and normal operation are included in these Operations Procedures.

A staged approach to start-up of the Cryogenic System has been planned and the operator training required for each stage is scheduled to precede the start of that phase of the operations. The First Sextant Test is the first stage which approximates full system operation, i.e., includes the distribution system and cools magnets in the Collider tunnel (Sextant 5).

Each segment of the performance based training will include classroom and field sessions to familiarize the operators with the OPM and the equipment. Cognizant engineers will be part of each crew and one will be selected to be responsible for operations during that shift.

R. EMERGENCY POWER SYSTEM

Eight diesel emergency generators have been installed around the RHIC Ring and at Building 1000P. The generators supply power via the Normal/Emergency power distribution systems at each of the locations as stand-alone sources of power actuated by local automatic transfer switches. The generators are sized to provide 150 kW, 480 VAC, 3 phase, 3 wire at 2, 4, 6, 8, 10, 12 o'clock and 1000P, and 300 kW 480/277 VAC, 3 phase, 4 wire at 5 o'clock. The systems have been designed to meet NFPA 110, for a Level II System.

The operating criteria of the generators and the Normal/Emergency power distribution system is as follows:

a. Should there be a loss of normal electrical power at any of the eight locations, whether it be local or sitewide, that loss of power will initiate a signal from the associated transfer switch to start the diesel powered generator.

b. After a period of 7 - 10 seconds, the transfer switch will transition from normal power source to diesel generated power. Only those electrical loads connected to UPS systems will remain unaffected during this 7 - 10 second period. All other loads will experience a loss of power for this period of time.

c. Once power has been successfully transitioned, the Normal/Emergency distribution system will be energized and continue to be fed from the generators for a period of approximately 24 hours before refueling is necessary or upon resumption of normal service. The normal power system will remain deenergized until normal service is restored.

S. DESIGN CRITERIA FOR NATURAL PHENOMENA HAZARDS

RHIC will conform to and/or use national consensus codes and standards as the design criteria for natural phenomena hazards (NPH). DOE Order 5480.25 requires that each facility be assigned a Performance Category as defined in DOE STD-1021-93, "Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Components." Since all the accelerator facilities are Low Hazard Class facilities, they fall in what is described in this Order as Performance Category 2 (PC-2), "Important or Low Hazard Facilities," (see Figure 2-1 page 5 from DOE STD 1021-93). Many of the support and ancillary buildings of the accelerator facilities fall into a Performance Category 1 (PC-1), "General Use Facilities."

The DOE Guidance Standard 1021-93 provides further guidance for classifying a facility as a PC-2; in addition to falling into a Low hazard classification, the following criteria would also classify a facility as a PC-2:

> "A structure, Systems and Component (SSC) that does not satisfy the referenced safety system criteria may also be placed in PC-2 from cost and mission considerations,; e.g., when SSC failure causes excessive downtime, SSC is very difficult to replace, or SSC replacement/repair is very costly."

The BNL accelerator facilities fall into the PC-2 classification due to both being low hazard class facilities, as well as having a difficult and costly mission to replace. The BNL accelerator facilities identified have defined missions critical to the overall mission of the Laboratory. They have been characterized as a Low Hazard as per DOE Order 5481.1B, Guidance for an Accelerator Facility Safety Program. This definition is somewhat restrictive for BNL accelerator operations, as it was intended for hospitals, fire departments, police departments, etc. However, ANSI A58.1 is less restrictive in their requirements for this type of facility. Even though the mission of these facilities is important to the Laboratory, some disruption of the operations could be tolerated should a NPH event occur and cause damage.

Construction of the former ISABELLE/CBA Facilities was in accordance with the applicable codes and standards in effect at the time of their construction. The primary standards then and currently are the Uniform Building Code, New York State Building Code and ASCE 7-95, "Minimum Design Loads for Buildings and Structures." Note, ASCE 7-93 is a revision of ANSI/ASCE 7-88. Since the time of the ISABELLE/CBA construction, the Long Island region has been reclassified to Seismic Zone 2 (see Appendix 22). New construction conforms to the current building codes.

T. STAR DETECTOR

1.0 Introduction

1.1 Description of STAR Experiment

The Solenoidal Tracker At RHIC (STAR) will search for signatures of quark gluon plasma (QGP) formation and investigate the behavior of strongly interacting matter at high energy density. The emphasis will be the correlation of may observables on an event-by-event basis. In the absence of definitive signatures for the QGP, it is imperative that such correlations be used to identify special events and possible signatures. This requires a flexible detection system that can simultaneously measure many experimental observables.

1.2 Detector Concept

The configuration of the STAR experiment is shown in Figure 3-T-1. Momentum measurements will be made at midrapidity over a large pseudo-rapidity range ($|\eta| < 2$) with full azimuthal coverage ($\Delta\phi = 2\pi$). Particle identification will be performed within $|\eta| < 1$. The detection system will consist of a time projection chamber (TPC), a silicon vertex detector (SVT) inside a solenoidal magnet to enable tracking, momentum analysis, particle identification via dE/dx and location of primary and secondary vertices, and an Electromagnetic Calorimeter (EMC).

Detectors will be installed to provide a collision geometry trigger. These include a central trigger scintillator barrel around the TPC, vertex position detectors near the beamline just outside the magnet, and calorimeters located in the region of the beam insertion magnets to selectively veto events according to the number of spectators. An electromagnetic calorimeter, will be located outside the magnet and used to trigger on transverse energy and measure jet cross sections. The major physics goals of STAR can be accomplished with this configuration of detectors. A time-of-flight system (TOF) surrounding the TPC for particle identification at higher momenta and forward time projection chambers (FTPC) outside the magnet to extend the η coverage are anticipated as upgrades. The STAR detector subsystems are summarized below and labeled in Figure 3-T-1 which is a three dimensional cut-away view of the STAR detector.

Summary of STAR Subsystems

Subsystem	**Purpose and Special Features**
Solenoidal Magnet	Provide magnet field for momentum determination.
Time Projection Chamber (TPC)	Provide tracking of charged particles and particle identification information.
Electromagnetic Calorimeter (EMC)	Photon detection and electron/positron identification and energy measurements.
Silicon Vertex Tracker (SVT)	Charged particle tracking close to the vertex. Identification of secondary tracks.
Central Trigger Barrel	Charged particle multiplicity information.
Forward TPC	Charged particle tracking at forward angles.
Vertex Positron Detector	Information on position of interaction.

2.0 Conventional Facilities and Systems

2.1 STAR Detector Facilities

The STAR detector facility is located in the 6 o'clock position in the RHIC complex. The facility consists primarily of the Wide Angle Hall (WAH), Assembly Building, and trailer complex.

The WAH accommodates the detector for experimental activities and support services. Connected to the WAH is the Assembly Building which is the primary location for assembling, maintenance and disassembling of the detector. Located in the Assembly Building are mechanical and electrical equipment rooms containing water, gas and electrical systems and equipment supporting the operation of the STAR detector. Adjacent to the Assembly Building is the Data Acquisition Room (DAQ) and Control Room. North of the DAQ room is a trailer complex that accommodates office space.

Additionally two three level electronics platforms were erected and attached to the STAR detector accommodating mechanical and electrical experimental equipment.

Hazards associated with these facilities include piping system (water and gas), electrical distribution systems and the beam pipe in the WAH. Systems have been designed, erected and will be operated in compliance with DOE, industry and BNL codes, regulations, standards, and policies respectively.

2.1.1 Wide Angle Hall

During operations, the STAR detector is located in the WAH (see Figure 3-J-1). Three sides of the hall are banked with earth to the roof line. The North side is connected to the Assembly Building. When the Collider is circulating beam, a concrete block shield wall is erected in the WAH separating it from the Assembly Building. Access and egress routes are provided for life safety. When the shield block wall is disassembled using the overhead crane, it is stored at the south end of the WAH. The WAH is equipped with emergency supply and exhaust fans, experimental gas venting lines, emergency lighting, as well as fire detection and suppression equipment. The beam line crosses approximately at the center of the hall 14 feet 2 inches above the floor level.

Along the West wall of the WAH is a festoon system that transports experimental cables from the South experimental platform to the DAQ room.

2.1.2 Assembly Building

Adjacent to the WAH is the 9790ft^2 Assembly Building equipped with a 40 ton crane used to support construction, installation, maintenance, and disassembling activities. The East End of the building is equipped with a two level mechanical and electrical equipment area and a gas mixing room. The mechanical equipment installed in this area includes water systems (pumps, heat exchangers, chillers, water treatment systems, water monitoring system) for the main STAR water system, magnet water system, modified chilled water system (MCWS) and magnet power supply/water cooled bus water system. Electrical equipment installed in this area includes the main magnet, trim and pole tip power supplies and associated equipment, and building/facility electrical distribution system.

Located just north of the exterior of the building is the main magnet power supply switchyard which includes the transformers and associated equipment for the STAR magnet. The experimental area of the Assembly Building is equipped with heating, ventilation and air conditioning equipment. The mechanical and electrical equipment areas are equipped with heaters and a ventilation system.

A gas mixing room is provided at the southeast corner of the building. This area accommodates the gas mixing and monitoring equipment for the experimental sub-systems associated with the STAR detector. The gas mixing room is air-conditioned.

2.1.3 Data Acquisition Room and Control Room

The data acquisition room and control room are located adjacent to the Assembly Building on the west side. These rooms contain the electronic racks and computer terminals that will analyze experimental data and will monitor and control the operations of the STAR detector. Each area is equipped with a heating, ventilation and air conditioning system.

2.1.4 Experimental Platforms

There are two experimental platforms erected and attached to the magnet support cradle. The north platform accommodates mechanical and electrical distribution systems supporting the operation of the experimental equipment. Systems and equipment include electrical panel boards, electrical power bridge that supports both magnet power and experimental power for operating the detector, air cooled transformers, electrical distribution equipment, water systems, experimental piping (water and gas) systems, magnet interlock cabinet and various control and signal cables.

The south platform primarily accommodates experimental electronics racks. Experimental racks are equipped with heat exchangers supplied by the modified chilled water system to accommodate heat removal. Electrical equipment installed on the platform includes electrical distribution equipment (panels, tray, conduit etc.), an interlock rack that houses gas, water and fire detection control equipment, and the initiating point of the experimental festoon system that transports experimental cables to the DAQ room. Mechanical equipment installed on the platform includes fire and gas detection equipment, fire suppression equipment for electronics racks with a value over $250K, and the modified chilled water distribution system (piping, valves, hoses, manifolds and electronics rack heat-exchangers) that removes heat generated in experimental electronics racks.

A maintenance catwalk, spanning the STAR detector, connects the north and south platforms. This catwalk is capable of being rolled, when in position, in the east/west direction. This movement permits access to experimental modules that are installed on the top of the main magnet back legs. Additionally this catwalk is removable permitting the transfer of the detector assembly (magnet and north and south platform) between the WAH and Assembly Building.

Experimental platforms and the maintenance catwalk are equipped with handrails and kick plates for personnel protection.

2.2 Conventional Utilities

2.2.1 Mechanical Systems

Conventional mechanical systems associated with the STAR detector are water systems for the main magnet, modified chilled water, and power supply/water cooled bus, fire and gas detection systems, and fire suppression systems. Mechanical systems that are considered RHIC infrastructure are the STAR facility cooling water system, compressed air, domestic water, and HVAC.

The STAR facility cooling water system consists of a cooling tower, chillers, heat exchangers, pumps, piping, valves and water treatment system. This system supplies low conductivity water to various heat exchangers that remove heat generated by equipment associated with the STAR detector. Heat exchangers and chillers are installed in the system to transfer heat and provide chilled water at the required operating parameters accordingly.

The main magnet water system is designed to remove heat generated from the STAR main magnet.

Main Magnet Water System Design Parameters

Parameter	Design
Fluid	Demineralized Water
Specific gravity	1.0
Supply Temp.	75°F
Return Temperature	95°F
Max. Pressure	225psig
Flow	1250gpm

Modified Chiller Water System is designed to remove heat generated by the following components:

Component	Sub-Component
TPC Heat Exchanger	TPC – electronics TPC outer field cage TPC tracking volume gas TPC inner field cage/SVT gas cooling sys.
Platforms Electronics	Electronic racks on experimental platforms
Data Acquisition Electronics	Electronic racks in DAQ Room
TOF cooling (future)	
EMC	EMC electronics on magnet
SVT cooling	Leakless cooling system

Modified Chiller Water System Design Parameters

Parameter	Design
Fluid	Demineralized water
Specific gravity	1.0
Supply Temp.	60°F
Return Temperature	70°F
Max. Pressure	150psig
Flow	360gpm

Power Supply/Water Cooled Bus Water System removes the heat generated from the magnet power supplies and the water cooled bus that is utilized to transfer electrical power from the power supplies to the main magnet.

Power Supply/Water Cooled Bus Water System Design Parameters

Parameter	Design
Fluid	Demineralized water
Specific gravity	1.0
Supply Temp.	85^{o}F
Return Temperature	118^{o}F
Max. Pressure	150psig
Flow	70gpm

2.2.2 HVAC

A common air conditioning system provides cooling to the Assembly Building or the WAH. The WAH and Assembly Building are both equipped with two-air handling units supplied by a single air-cooled liquid chiller. The location of the STAR detector, WAH or Assembly Building, will determine the air handling units placed in service. The design parameters of the systems are 75^{o}F +/- 3^{o}F with a relative humidity at 50 to 55% regulated to +/- 5%.

HVAC systems are provided for the DAQ and Control rooms.

A ventilation system is provided for the mechanical and electrical equipment rooms in the Assembly Building.

2.2.3 Electrical Utilities

Electrical systems associated with the STAR detector are 1) general building power, 2) main magnet power, 3) experimental electronics power, 4) grounding plan and 5) STAR interlock system.

In general power is supplied to 1006 facilities via two separate switchyards. Yard 1006A supplies the general buildings and the experimental power distribution systems. Switchyard 1006C supplies the main magnet power supply distribution system and general building power. All of the electrical distribution systems associated with STAR have been designed and installed in accordance with the National Electrical Code and relevant Brookhaven National Laboratory and RHIC specific requirements.

2.2.3.1 Main Magnet Distribution System

Power originates from the 13.8 kV feed into switchyard 1006C. From the yard there is a direct feed to the main magnet transformers (located in the magnet switchyard) via associated switches and breakers. From the transformers the power is distributed to the main magnet power supplies located on the second floor of the Assembly Building which in turn is distributed to the main magnet via water-cooled bus. An elaborate electrical bridge, that is removable and transferable between buildings, has been installed to support the distribution of the power to the magnet depending on the location either in the WAH or Assembly Building.

An additional feed from the 13.8kV switchgear goes to a substation located in the 1006C yard. This substation feeds the magnet pole tip transformers (located in the magnet switchyard) and pole tip power supplies (located on the second floor of the mechanical building), water systems discussed in section 4.9.2, and Assembly Building electrical distribution system (e.g. overhead crane, outlets, and future applications.)

2.2.3.2 Experimental Power

Power that is utilized for experimental electronics and data processing originates from the 1006A yard. 480 VAC power from this yard is feed to distribution panel A1 located in the DAQ room. The experimental electronic platforms receive power form this panel. From panel A1 power is distributed to locations either in the WAH or Assembly Building depending on the location of the STAR detector. From these locations power enters the North platform via the same electrical bridge discussed previously. Once on the platform power is distributed to transformers to generate what is known as “clean” power (208/120VAC) or conventional power. “Clean” power is distributed to the South electronic platform via a series of electrical distribution panels. From these panels power is distributed to a series of dedicated, by subsystem, electronic racks. Subsystems within the STAR experiment have been assigned specific electronic racks. Each electronic rack has its own circuit breaker panel located at the top of each rack.

Clean power is also provided to the DAQ room in support of the data acquisition equipment installed in his area.

Conventional power is distributed on the North platforms to support mechanical equipment.

2.2.3.3 Grounding Plan

Because there are many small voltage and current signals in the STAR detector, it is necessary to insure that there is a low electrical noise environment. Consequently, precautions have been implemented when planning and installing the grounding system. Improper grounding can produce voltage gradients and unanticipated electrical paths. These can produce unanticipated currents and consequently electrical noise. Therefore, a well-defined grounding plan has been installed that satisfies experimental concerns as well as the National Electrical Code. The entire South platform, equipment installed on the platform and the main magnet cradle have been bonded and are grounded to a specific building column in the Assembly Building regardless of the location (WAH or Assembly Building) of the detector. This grounding point is also monitored and alarmed providing notification if the grounding plan has been violated.

In the DAQ room a grounding grid system has been installed under the raised floor in this area for similar purposes. The grounding plan in this room is not monitored.

2.2.3.4 STAR Interlocks

A series of interlocks have been installed both in the overall STAR integration program and in each experimental subsystem. Typically interlocks include smoke and heat detection, gas detection, water leak detection etc. Depending on the detector activated the interlock system would have the capability of isolating electrical power to a experiment rack row to isolation of the entire experimental and magnet electrical system and initiate the mechanical purge system of the TPC gas system. For a detailed description of the STAR interlock system see Appendix 31.

2.3 Fire Protection

For detailed information regarding fire protection engineering features, see the Fire Hazard Analysis in Appendix 32 and fire barrier exemption in Appendix 33. The recommendations contained in the Fire Hazards Analysis are being tracked as Project commitments to be implemented prior to completion of the ARR for the detector. The exemption request discussed in the Fire Hazard Analysis has been filed.

2.3.1 Three levels of fire protection have been incorporated into the design and operation of the STAR detector. These levels include prevention, detection and suppression.

Prevention is accomplished by (1) limiting the amount of combustible materials incorporated into the design of experimental equipment; (2) implementing the National Electrical code into the design of AC and DC distribution systems; (3) periodically performing a walk-through of the area; and (4) incorporating fire and smoke barriers into the design of the facility and equipment.

Fire detection is accomplished with the installation of smoke detectors. The WAH and Assembly Building are equipped with HSSD (High Sensitive Smoke Detectors). The east and west face internal to the STAR magnet are also equipped with the HSSD system. The remainder of the facility is equipped with spot detectors. Experimental equipment racks installed on the platforms and in the DAQ area are also equipped with spot detectors.

A wet pipe suppressor system is installed throughout the WAH, Assembly Building, DAQ and Control. Additionally, an inergen suppressant systems are installed in any experimental electronic rack on the platform or in the DAQ room, whose value exceeds $250/c.

2.4 Hazardous and Toxic Materials

The passive material in the STAR electromagnetic calorimeter (EMC) is lead and the detector contains ~150 tons of lead. This lead will be located in finished modules enclosed in light-tight aluminum or stainless steel boxes assembled elsewhere, and thus not ordinarily handled. Lead may be used in other STAR systems for shielding. All personnel needing to handle lead will be trained in the safe handling of lead.

Beryllium is used in various parts of the Silicon Vertex Detector (SVT) (e.g. in various parts designed to hold the silicon plates in place) and the beam pipe. The beam pipe will have an epoxy coating on the outside diameter and is UHV cleaned on the inside. The coating and cleaning operations will eliminate the fine dust and thus the particulate breathing hazards. The beryllium components in the SVT will have a coating, or seal, to keep them from creating beryllium dust. Gloves will be worn when beryllium components are handled. Individual who routinely handles the

SVT components will receive formal training in handling beryllium. All handling, maintenance and/or working with beryllium will be performed in accordance with Laboratory requirements.

Materials such as paints, oils, solvents, cleaning fluids etc. that are in the facility will be stored in accordance with Laboratory policy. "MSDS" for materials will be maintained in the facility.

Gas cylinders are stored in the gas storage area East of the Assembly Building The gas stored in this area is nitrogen, methane, argon and helium. The storage facility and components have been designed and installed in accordance with Laboratory policy. A gas mixing room is provided in the Assembly Building for experimental mixing of the gas. Piping is hard piped. In line monitoring is provide to insure proper mixing ratio for gases; e.g., P10 (10% methane in argon) is maintained.

A green "Emergency Information" Sign is posted at the Assembly Building door located in the Northwest corner of the building. The sign identifies the following:

Individuals – to call in case of an emergency

Location – location of potential hazards in the building

Radiation Hazards

Fire Hazards

Health Hazards

Other - information pertinent to hazards in the facility

U. PHENIX DETECTOR

1.0 Introduction

1.1 Description of the PHENIX Experiment

The primary goals of the heavy-ion program of the PHENIX collaboration are the detection of the quark-gluon plasma and the subsequent characterization of its physical properties. To address these aims, PHENIX will pursue a wide range of high energy heavy-ion physics topics. PHENIX has chosen to instrument a selective acceptance with multiple detector technologies to provide very discriminating particle identification abilities. Additionally, PHENIX will take advantage of RHIC's capability to collide beams of polarized protons with a vigorous spin physics program.

1.2 Description of the PHENIX Detector

Fundamentally, the PHENIX detector consists of a large acceptance charged particle detector with four spectrometer arms--a pair of spectrometers measuring electrons, photons and hadrons which straddles mid-rapidity, and a pair of muon spectrometers at forward rapidities--all working together in an integrated manner. Each of the four arms has a geometric acceptance of approximately one steradian. The magnetic field in the volume of the collision region is axial, while the magnets of the muon arms produce radial fields.

The first part of each muon arm (following a thick hadron absorber) contains three stations of cathode strip tracking chambers. The back part of each arm consists of panels of Iarocci streamer tubes alternating with plates of steel absorber.

The PHENIX subsystems are summarized in Table 3-U-1 and labeled on Figure 3-U-1 which is a three dimensional cut-away view of the PHENIX detector.

2.0 Conventional Facilities and Systems

2.1 PHENIX Facilities

The PHENIX experiment occupies several buildings and areas in the 8 o'clock intersection region of the RHIC Complex. Building 1008 is the PHENIX Experimental Hall (PEH), Building 1008A is the PHENIX Counting House (CH) and Experimental Support Building (ESB). Magnet power supplies are located on a balcony in the 1008B RHIC Cryogenic Support Building, and 1008C is the pump house for water cooling systems. Gas storage and mixing areas are located outside along the south side of the site. Figure 3-K-1 shows these areas, and they are described further below.

Figure 3-U-2 shows a view of the PHENIX detector in the PEH at the position in which it will be located during data acquisition. A shield wall divides the PEH into an Interaction Region (IR) where the detector is located during data taking and an Assembly Area where detector assembly, maintenance and modification can take place. The shield wall has a large rolling door which allows the four large mobile pieces of PHENIX to be moved between the IR and assembly area for installation, major maintenance and upgrades. There will be an entrance labyrinth and a small rolling plug door, with appropriate safety interlocks for access to the collision area by personnel and small equipment.

TABLE 3-U-1

Summary of PHENIX Subsystems

Subsystem	Purpose and Special Features
Magnet Systems: Central Magnet (CM) Muon Magnet North (MMN) Muon Magnet South (MMS)	Provide magnetic fields for particle tracking and identification. same same
Multiplicity and Vertex Detector (MVD)	Precise vertex location, $d^2N/d\eta d\phi$
Beam-beam counter (BB)	Start Timing, fast vertex
Drift Chambers (DC)	Good momentum and mass resolution.
Pad Chambers (PC)	Pattern recognition and tracking for non-bending direction.
Ring Imaging Cherenkov counter (RICH)	Electron identification
Time Expansion Chamber (TEC)	Pattern recognition, dE/dx
Time-of-Flight (TOF)	Hadron identification
Electromagnetic Calorimeters PbSc PbGl	 Good e/π, K/e separation, dE/dx Photon detection
Muon Chambers (μT)	Tracking for muons
Muon Identifier (μID)	Steel absorbers and chambers for μ/hadron separation

The rolling doors have mechanical and electrical stops. The large door is not interlocked to PASS. It will be opened only when the machine is down for extended periods and controlled by an administrative procedure as is normally done for removing shielding. The small rolling door will be used for personnel access. This, with the labyrinth door, assures that two egress routes are available whenever personnel are in the intersection region.

A system of steel tracks is in place to facilitate moving the movable portions of the detector from the IR to the PEH Assembly Area, when the large rolling door is removed. The existing 40-ton crane will be used in the installation of the rolling door and remain in the assembly area. A 12-ton crane is installed to serve the interaction region behind the wall.

Adjacent to, but separate from the PEH is a single story Counting House between the PEH and the ESB that adds about 600 square meters of additional floor space. The Counting House provides space for the data acquisition electronics and computers, control equipment and monitoring consoles. The ESB contains work areas and an electronics shop to support PHENIX operations.

2.2 Common Systems and Utilities

Utility electrical systems, heating-ventilation-air conditioning (HVAC) systems and other utility systems are needed for detector operation. Electrical and closed-loop cooling systems for the magnets and electrical systems involved in data acquisition, detector control and detector operation (i.e., high voltage systems for detector biasing) will be discussed in sections devoted to each particular sub-system.

The AC power distribution for PHENIX is described in Section 2.2.1 and the PHENIX policy for electrical grounding is presented in Section 2.2.2. The PEH, and Counting House HVAC systems and proposed cooling water sources and distribution described in Sections 2.2.3 and 2.2.4, respectively.

2.2.1 PHENIX Electrical Power Distribution

The hazards presented by PHENIX Electrical Power Distribution are in the "Routinely Accepted" category and are mitigated by adherence to applicable portions of the National Electric Code and the RHIC OPM 5.1.5.0.1 Supplemental Electric Safety Requirements in the design, construction and operation of the systems.

2.2.1.1 Description

The PHENIX Experiment complex at the PEH and service Buildings 1008, 1008A, 1008B, and 1008C are connected to the BNL 13.8 kV AC distribution system. The 13.8 kV system consists of overhead and underground service originating at the BNL 631 substation.

The BNL 13.8 kV system is connected to two 1008 complex substations where this voltage is stepped down to 480 volts AC for distribution throughout the PHENIX buildings. One substation is located adjacent to the North of 1008A and is accessed via the inner ring road. The other is located adjacent to service Building 1008B and is accessed via the outer ring road.

Counting House Power

The PHENIX Counting House 480 volt AC Power originates at the substation air circuit breaker. This breaker supplies the Counting House 480 volt breaker panel. This panel consists of eight molded case circuit breakers equipped with shunt trip coils and position indicating switches capable of interfacing with breaker monitoring and control panel.

Five circuit breakers supply 480 volt AC power to the respective five step down transformers which supply the I.R. Electronics racks. Each transformer secondary winding (208 VAC) is connected to a cable termination box located in the PEH. The IR breaker sub-panels which feed the racks are connected to the termination box.

Another circuit breaker supplies the counting house 208 volt AC distribution breaker panel and it is distributed from this panel to breaker sub-panels located only in the counting house. The 208 volt distribution is provided for the counting house electronics racks, UPS system, and ONCS Computer terminals.

A seventh circuit breaker supplies the counting house lighting transformer. The associated breakers sub-panel provides lighting and receptacle power. The remaining circuit breaker is a spare.

PHENIX Experimental Hall Normal AC Power

The PEH 480 volt AC Power originates at substation 8A at an air circuit breaker . This breaker supplies the utility room normal AC bus. This bus is connected to a number of power panels making up the PEH as well as the RHIC tunnel sextant 7 and 9 480 V distribution network.

PHENIX Complex Emergency AC Power

Upon loss of off site power, the diesel generator will start and provide backup power to an emergency bus via the auto throw-over switch. The emergency bus is connected to other “emergency” power panels located throughout the PHENIX buildings. Emergency power will be distributed to safety critical equipment such as the IR ventilation fans, IR lighting and specific components of the PHENIX Gas System.

Uninterrupted Power Sources (UPS)

The PHENIX Experiment requires that certain equipment be provided with UPS power in order to function properly during a loss of regular power service or other abnormal events.

2.2.2 Electrical Grounding

The PEH building power is installed so that there is a separate equipment grounding conductor back to the service panel. Additional safety grounds are available as needed in addition to the AC power distribution grounds. A separate ground pad is installed for the CM and MM power supplies. With the exception of the EMCal, the frame of each detector will be electrically isolated from the steel support structures at its mounting points and a bonding cable supplies the safety ground at a point chosen to create minimum electrical noise.

2.2.3 Heat, Ventilation and Air Conditioning (HVAC)

Air conditioning is provided to the PEH to remove excess magnet and electronics heat and to maintain the dew point below the cooling water temperature to prevent condensation. The chiller is located outside the ring just behind the PEH, and the air handling equipment is mounted on the PEH roof. Conditioned air enters the PEH through one of two 54-inch diameter ducts in the west wall with the return through the other 54-inch duct. Flow rate is about 37,000 cfm with about 1500 cfm fresh air exchange. Air exchange with the RHIC tunnel is restricted by barriers erected in the tunnel by the RHIC project. These walls are designed to isolate the PEH from potential oxygen deficiency hazards (He leaks), and separate the emergency ventilation system for the tunnel from that of the PEH.

Emergency ventilation for the PEH is provided through the same 54-inch duct pair used for the air conditioning. When the emergency ventilation system is required, the air conditioning system is turned off automatically, and the two ducts are opened by dampers to the emergency exhaust and inlet fans mounted at the top of the 54-inch stacks. Air is then exchanged with the outside at the rate of about 20 changes per hour.

2.2.4 PHENIX Cooling Water

Cooling water is provided to PHENIX at 20 degrees C to cool the magnet coils, electronic racks and several of the detectors. The pump house and cooling tower are located outside the ring just behind the PEH. Water lines are routed through the same openings in the west wall as the magnet power and control cables. Water for the counting house electronic racks is routed through the IR, through the permanent door sill of the shield wall, then into the counting house.

2.2.5 PHENIX Safety System

PHENIX is a complex system with potential hazards typical of large detector systems. While some of these hazards can be categorized as routinely accepted, others are classified as PHENIX specific hazards. PHENIX has adopted the approach of providing a Safety Monitor and Control System (SCMS) that will continuously "police" the PHENIX sub-systems and local environment inside the PHENIX Experimental Hall.

The PHENIX SMCS will be an active, real time, monitoring and control system that will take inputs from gas, smoke, and fire detection systems as well as the emergency "crash button" circuit. It can also accept a crash signal from any one of the PHENIX sub-systems.

Upon detection of an off normal situation from any input, or activation of a crash button, the SMCS can respond by tripping a master contactor that will effectively reach back to the power breakers and "kill" all clean and utility power inside the hall. In parallel with the power shutdown, the SMCS can, depending on the condition, also initiate the following actions:

1. Shutdown of detector gas; initiate a safe purge
2. Signal to "PASS" (emergency exhaust fans, HVAC, etc.)
3. Communication/Alarm to the local Fire Control Panel (Firehouse)
4. Communication/Alarm to MCR
5. Communication/Alarm to PHENIX Control Room

The Safety Monitor and Control System receives its electrical power from an independent, non-common branch circuit. The branch circuit will be tied into the Emergency Power System (diesel generator) to assure continuous operation during long term power outages. UPS will protect against dips and short term interruption.

2.2.6 PHENIX Rack Interlock System

Much of the electronics in PHENIX will be housed in enclosed racks mounted on the carriages and magnets. These racks contain high voltage for the detectors, low voltage power for the on-detector electronics, as well as some detector electronics. These racks have an internal interlock system capable of sensing temperature, smoke, coolant loss, and local manual crash. They can also be powered off by remote control.

2.2.7 PHENIX Gas Storage Shed

Ten different gases and air are used for working (process), purge, inerting or cooling gas in PHENIX. The gases are stored as compressed gases, liquefied gases, or cryogenic liquids. Because of the dangers associated with compressed and flammable gases, and the potential for cryogenic hazards, these gases are stored remotely (Figure 3-K-1). Cylinders and cryogenic storage containers reside on a concrete pad open on all sides. A five foot high barrier wall separates flammable from non-flammable gases. Concrete filled pipe bollards protect the pad area from intrusion by stray vehicles. No electric power service is required and lighting is by battery power. The pad is accessible by blue stone driveway from Ring Road. Frequent trailer drops are anticipated to service the weekly recharge schedule.

2.2.8 PHENIX Gas Mixing House

The PHENIX Gas Mixing House is provided with NEC Class I Division II flammable atmosphere rated fire detection. Detection is spaced at less than 400 sq. ft. Manual fire alarm boxes are provided outside of the building. The service complies with NFPA 72 and is connected into the PEH building system. Local audible/visual devices are provided to alert the building occupants.

2.2.9 PHENIX Gas Vent Systems

Detector gas systems, both recirculating and single pass, during normal operation continually take make-up gas while venting an equal amount outside the IR through the Low Capacity Vent Stack (LCVS). Exhaust pipes vent to this 30" diameter shaft in the South West corner of the IR about twenty feet up the West wall. A special fan arrangement ensures a constant and steady back pressure for all systems and dilutes the mixture of all flammable gases to less than 25% of the Lower Explosive Limit. This fan must run continually and will be interlocked.

A second and similar stack in the North West corner is used for off-normal modes of operation such as: detector purges, overpressure venting, and emergency pump-downs. The stack ducting and fan exhaust is strategically oriented to vent even the inerted stack gases away from potential sources of ignition and building air-handler intakes. The vent stacks satisfy the criteria for venting of flammable gases.

2.3 Fire Protection Systems

For complete information regarding the fire protection engineering feature, see the Fire Hazard Analysis and fire barrier exemption in Appendices 33 and 34. The six recommendations contained in the Fire Hazard Analysis are considered action items to be implemented prior to achieving operational status. The exemption request discussed in the Fire Hazard Analysis has been filed.

2.3.1 PHENIX Experimental Hall

<u>Highly Sensitive Smoke Detection System (HSSD)</u>

To provide early warning in both the Experimental Hall and the Assembly Hall, the PHENIX experimental hall is provided with a Highly Sensitive Smoke Detection System (HSSD). The ceiling heights in excess of 50 ft. prompted the need for a detection system with greater sensitivity than the standard spot type of detectors. The air aspirating type of detection has a ceiling mounted network of pipe. The sampling ports have been designed in accordance with the Underwriter's Listing of the manufacturer. The system has been tested to verify conformance with design response time. Twenty four hour battery backup and emergency generator power has been supplied.

The HSSD system provides three level of alarms. All three alarms report back to the BNL on-site fire/rescue group via the Site Fire Alarm System. The first level alarm is a local alarm (intended for the control operators). The second level alarm also sounds locally, but requires investigation by Fire/Rescue. Third level alarms require full response by Fire/Rescue. A third level alarm will evoke electrical shutdown, flammable gas detector purge sequences, emergency exhausts ventilation for the PEH, building evacuate signals and response by emergency personnel. The system complies with NFPA 72 and the UL listing. Building fire alarms have battery backup (24 hour capacity) and emergency generator power (24 hour capacity). This system, combined with the on-site Fire/Rescue Group, satisfies the DOE requirement for a redundant fire suppression system for loss potentials over 65 Million dollars.

Preaction Sprinkler System

To provide suppression of a disastrous level fire in the Experimental Hall and the Assemble Hall, a preaction sprinkler system has been installed. Installation of the sprinkler system complies with NFPA 13. Heat detection has been installed in accordance with NFPA 72, to activate the preaction system. Waterflow and detection is tied into the building fire alarm system and will activate building wide audible/visual devices upon third level alarm. Air pressure and valve supervision report through the site fire alarm system as supervisory devices.

Standpipes are provided to the PEH and AH via the wet pipe standpipe system serving the RHIC Accelerator Tunnel.

2.3.2 PHENIX Detector

Electronics Cabinets

On the PHENIX Detector, much of the electronics will be house in NEMA 12 rated enclosed racks. Since these racks are purged with air, the ceiling level detection will not be effective. Given the high value of the equipment, smoke detection has been installed in the racks. Each rack is provided with a spot type smoke detector. These standard detectors will provided ample sensitivity given the fact the racks are less than 8 ft. tall, 4 ft. wide and 4 ft. deep. The detectors in the racks will be grouped to allow interlocks to shut down power to specific racks upon alarm.

HSSD on the Detector

An HSSD System will be installed within the PHENIX Detector. The detection system will monitor the volumes around the interior electronics. Similar to the PEH HSSD, the units will have three levels of alarm. The first level will require operator attention. The second will involve the operator and the Fire/Rescue Group for investigation. A third level alarm will evoke electrical shutdown, flammable gas detector purge sequences, emergency exhausts ventilation for the PEH, building evacuate signals and response by emergency personnel. The HSSD Control Panel is tied into the building fire alarm system and will activate building wide audible/visual devices upon the third level alarm. Building fire alarms and the HSSD system have battery backup (24 hour capacity) and emergency generator power (24 hour capacity).

Combustible Gas Detection on the Detector

Within the PHENIX Detector, an air sampling combustible gas detection system will be installed for experimental operations using flammable gases. The air sampling system consists of a network of tubes that connect to a selector valve system. The selector valves and detection assemble will be located outside of the PEH. Sample points will be located on and around the detector based on potential leak points, potential collection points, normal air flow patterns, and the detector's construction. There is no installation standard for this type of application. A commercial system is used with a selector valve system to cycle through the sampling tubes and monitor combustible gas levels. Detection cycles and lengths of sampling points will ensure response to a leak within 90 seconds. Individual channel values are displayed and programmed for alarm and output functions. There will be warning levels in the ppm range, in which operators will investigate and monitor the situation. Higher reading will force action levels at 25 % of the Lower Explosive Limit, which will entail notification of Fire/Rescue, electrical shutdowns, vent and purge of detector chambers. The gas detection system will be on emergency power to provide continued operations during power outages.

2.3.3 PHENIX Counting House

The PHENIX counting house is protected by a preaction sprinkler system. Design and installation complies with NFPA 13. Smoke detectors have been provided at 400 sq. ft. spacings in areas were high value electronics are present. Heat detection at 400 sq. ft. spacings are present in other areas. Manual fire alarm boxes have been provided at the exits. Local audible/visual devices are provided to alert the building occupants. Building fire alarms have battery backup (24 hour capacity) and emergency generator power (24 hour capacity).

The PHENIX counting house has been isolated from the adjacent mechanical spaces and tech shops by a one hour fire wall.

V. SMALL EXPERIMENTS

There are two small experiments, BRAHMS and PHOBOS, that are part of the "Day-1" RHIC complex. In the future, other experiments of a similar scale may be added to the experimental program. Since the current small experiments do not present hazards that warrant a dedicated SAD based on their scope and scale, they will not be reported in detail as with STAR and PHENIX. With regard to review, documentation and authorization, the small experiments went through the same process as the large experiments, and complete safety documentation exists in the Project ES&H files. The process included:

1. Preliminary ES&H review by the Experiment Safety Committee as per RHIC OPMs 5.1.3.5 and 9.16.
2. Review of the detailed design of each major subsystem, including issues that relate to integration, as per RHIC OPMs 5.1.3.5 and 9.16.
3. Operation Readiness Reviews of each major subsystem before initial startup, as appropriate.
4. Accelerator Readiness Review to authorize operation of the integrated system for Commissioning.

If there are changes to the small experiments or new small experiments are proposed that introduce large-scale hazards; e.g., use of a large volume of liquid hydrogen, then a determination will be made by the Experiment Safety Committee based on potential consequences and the need to publish a dedicated safety analysis in the RHIC SAD. Otherwise, current and future small experiments will be handled generically as described above.

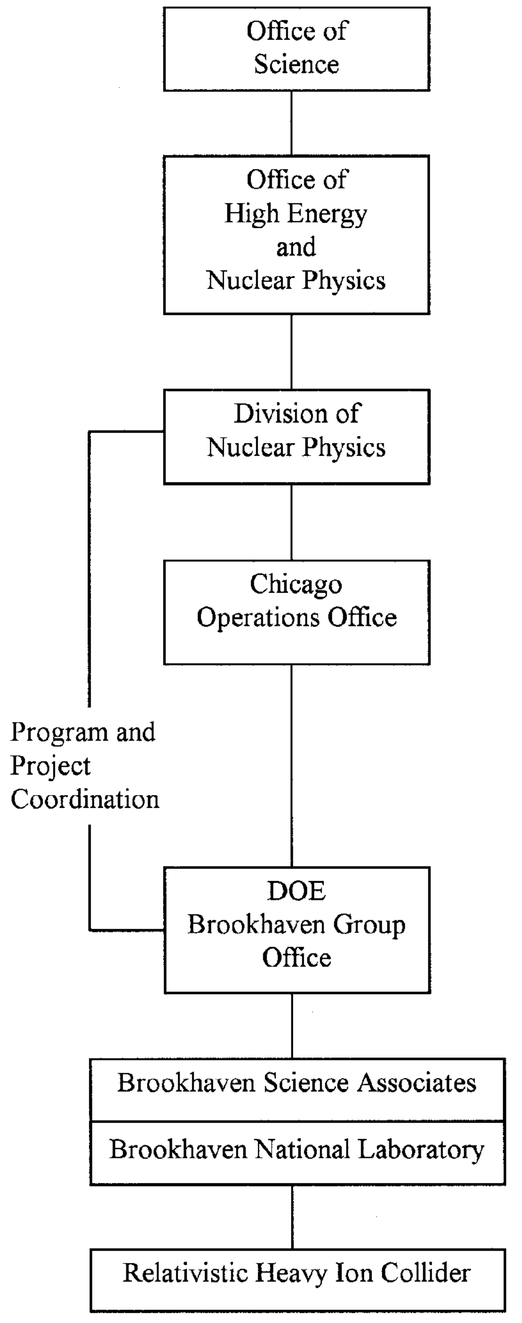

Figure 3-B-1. Organization of DOE, BSA, BNL and RHIC.

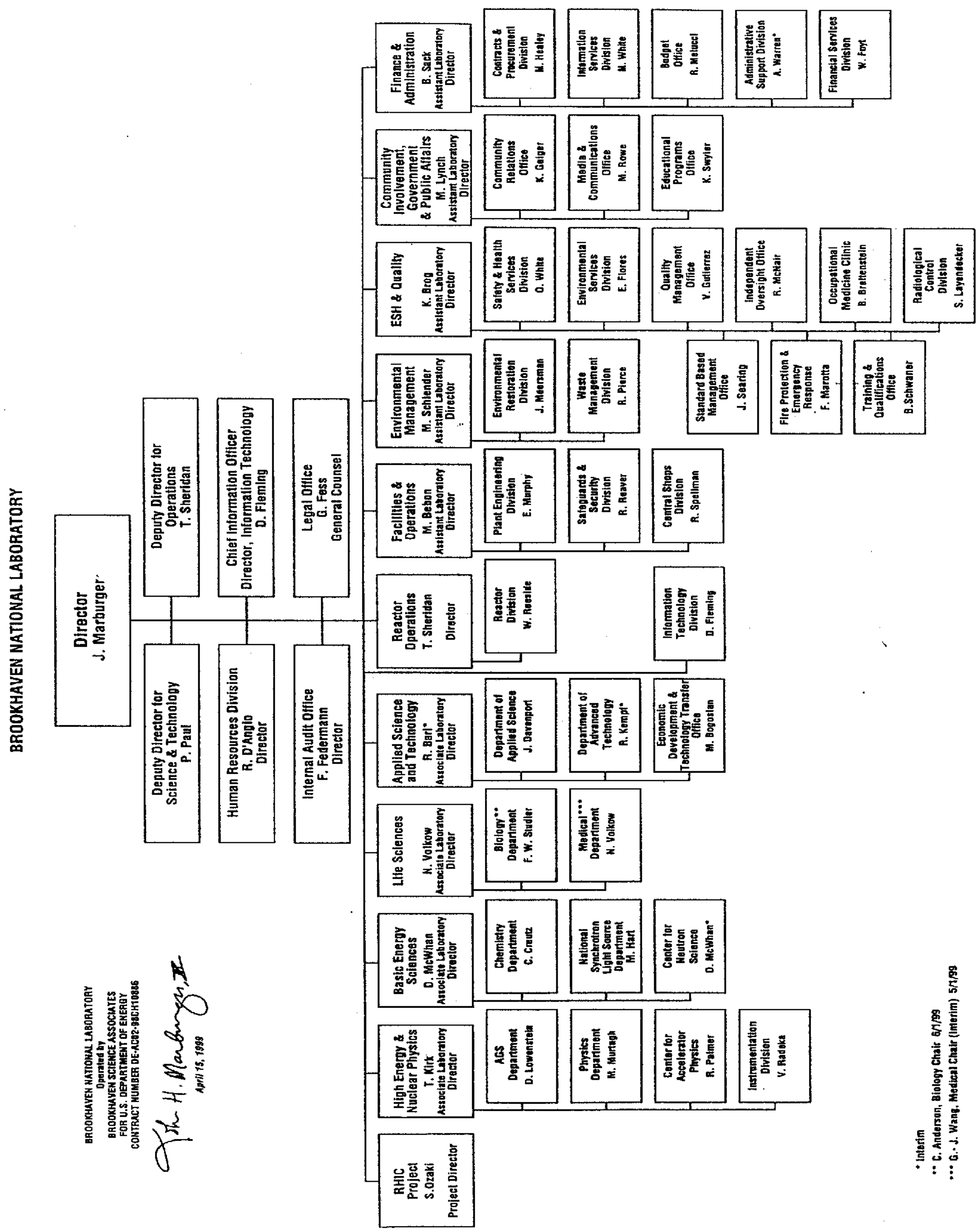

Figure 3-B-2. Laboratory Organization Chart.

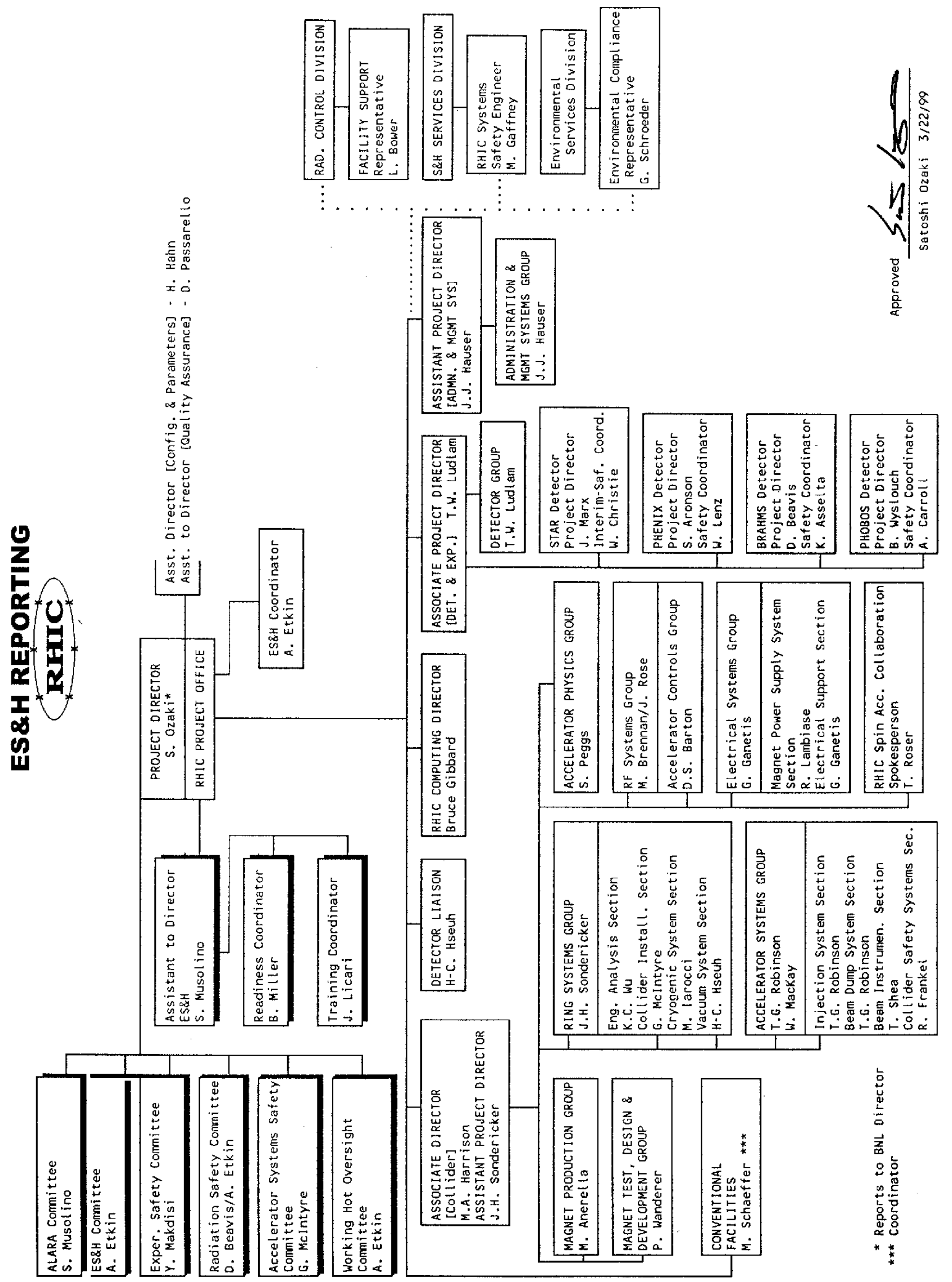

Figure 3-B-3. ES&H Reporting Chart.

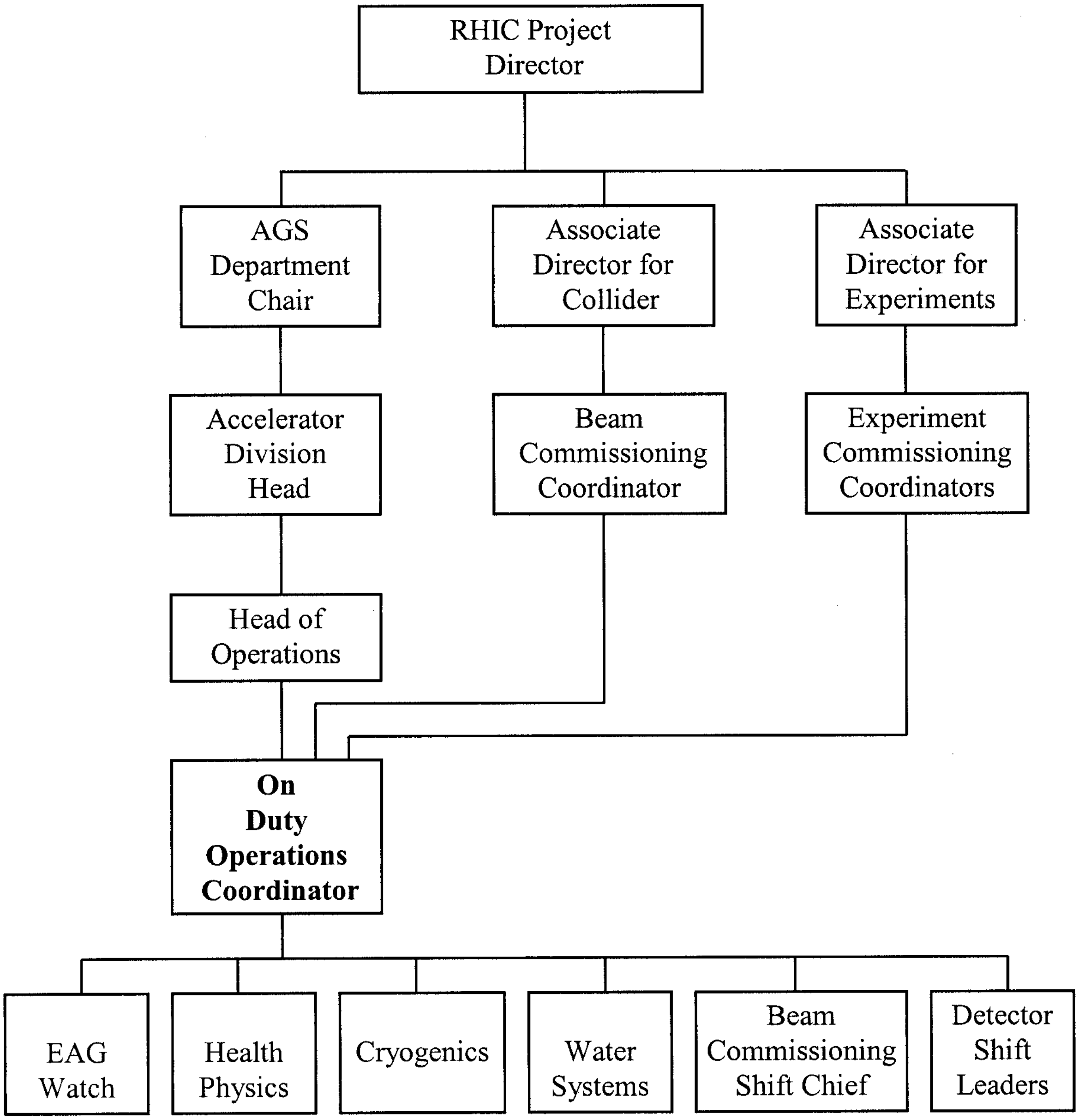

Figure 3-B-4. Operating Organization for RHIC Commissioning.

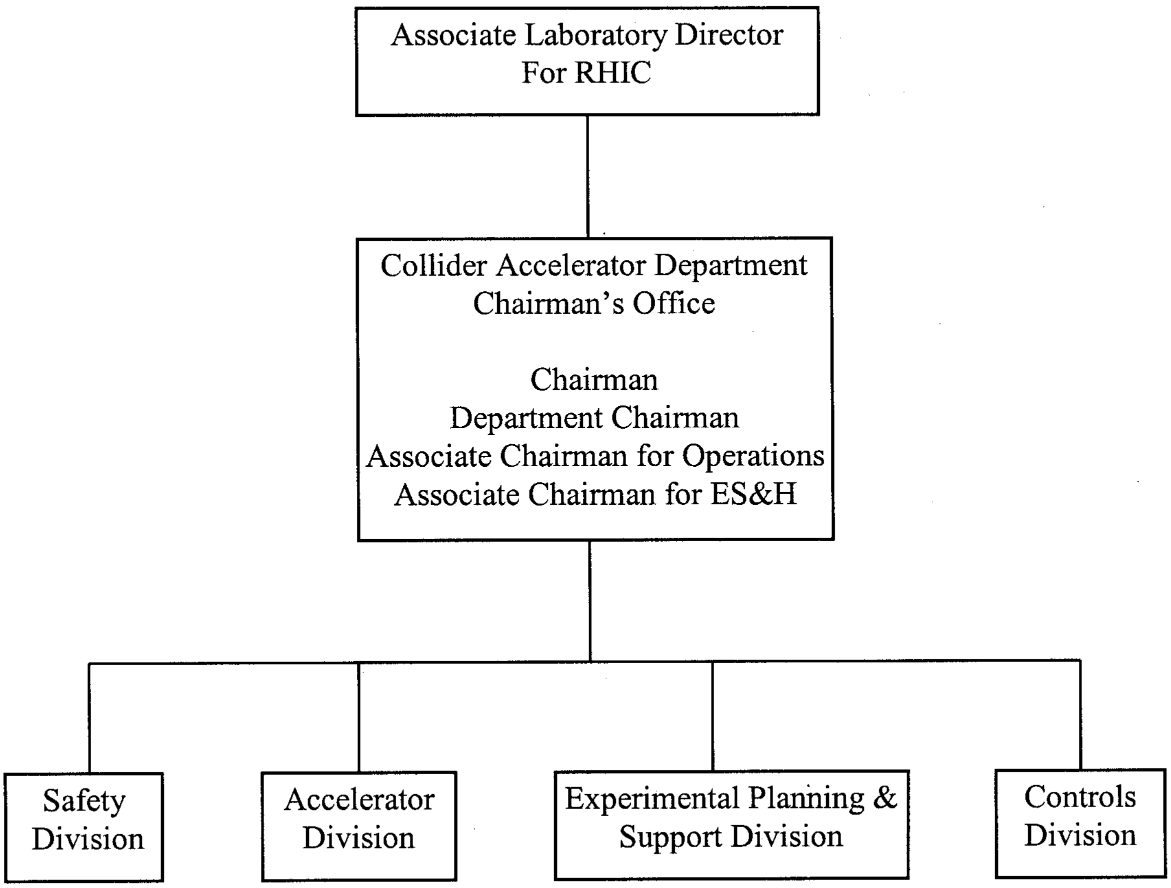

Figure 3-B-5. Collider Accelerator Department Organization Chart.

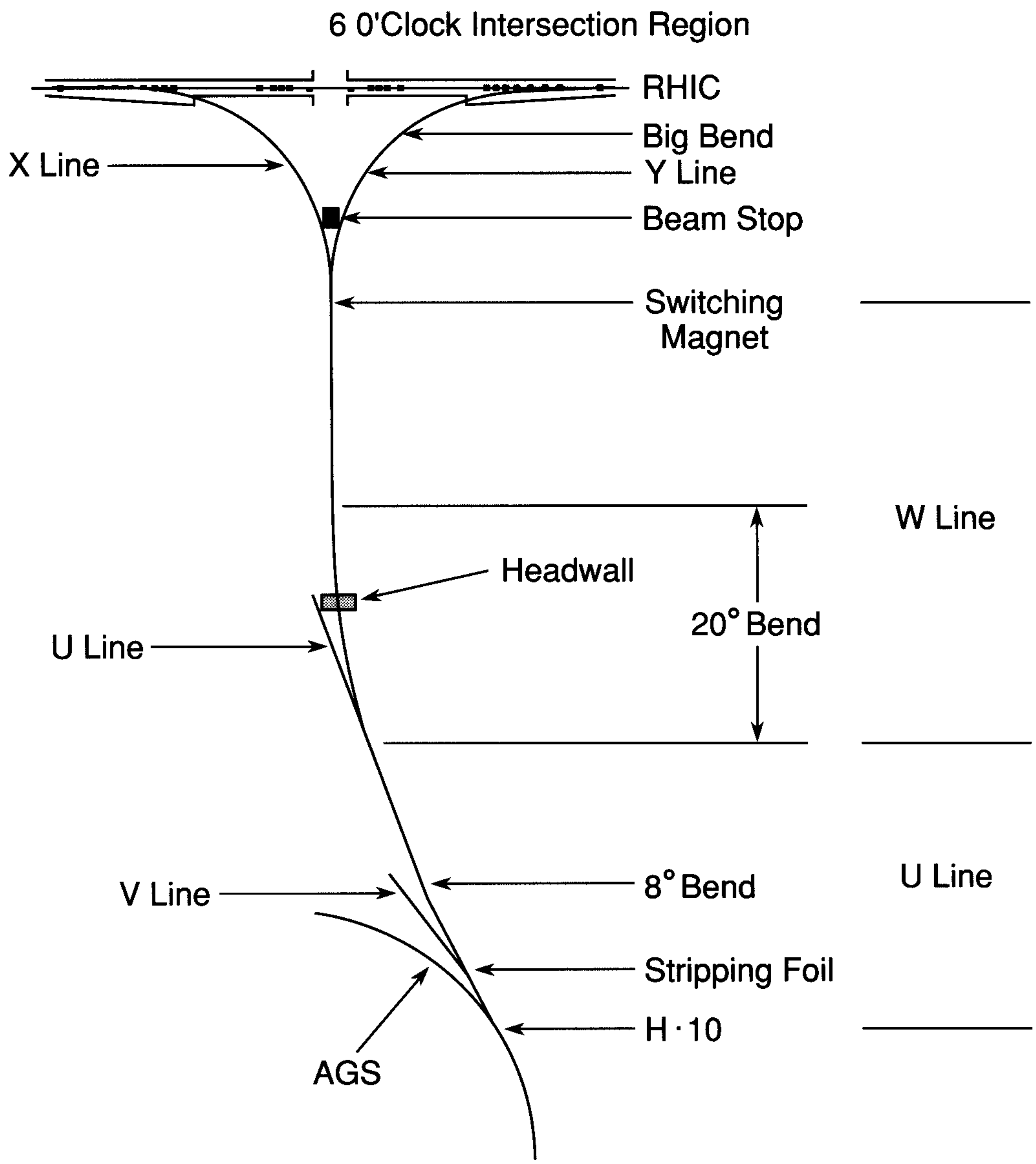

Figure 3-E-1. Schematic of the Transfer Line.

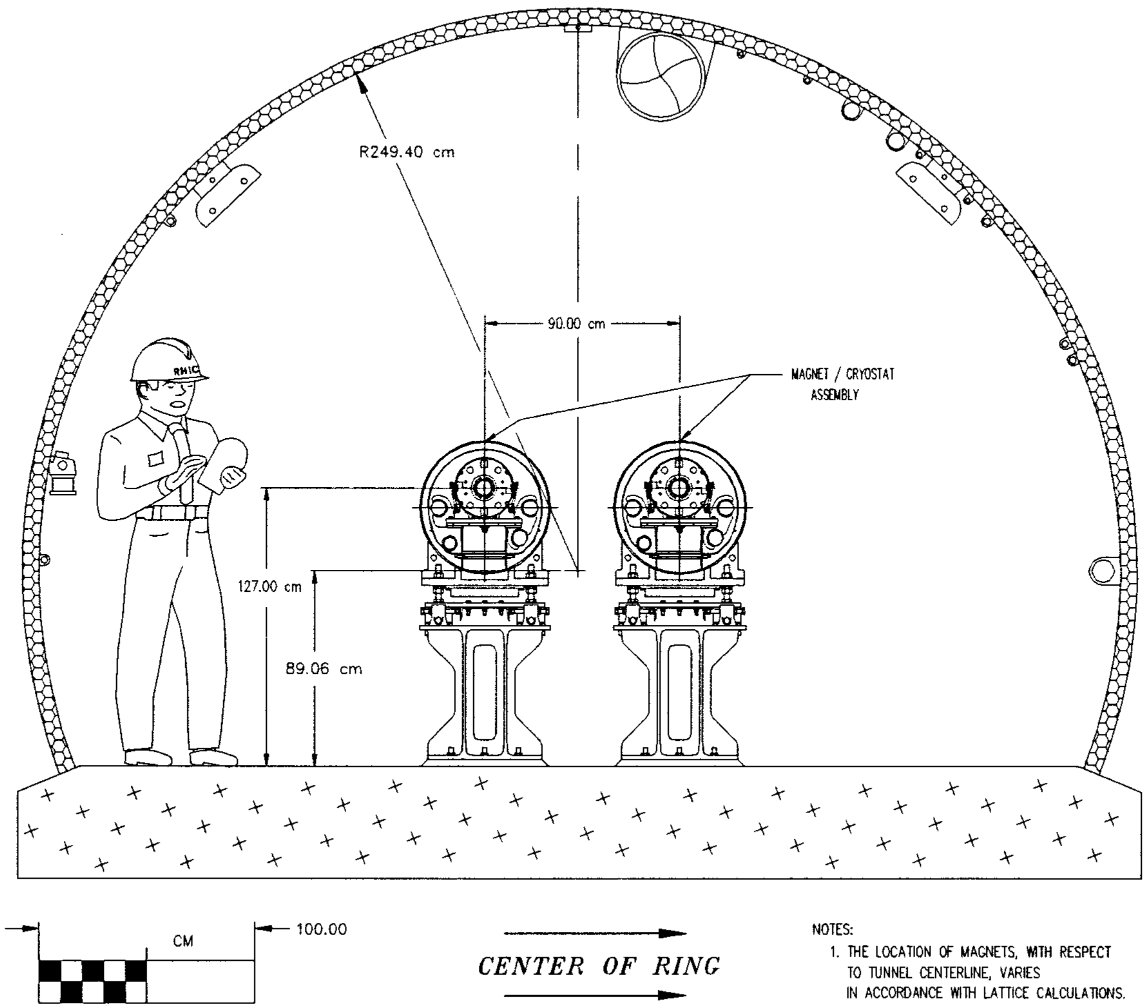

Figure 3-F-1. Tunnel Cross Section.

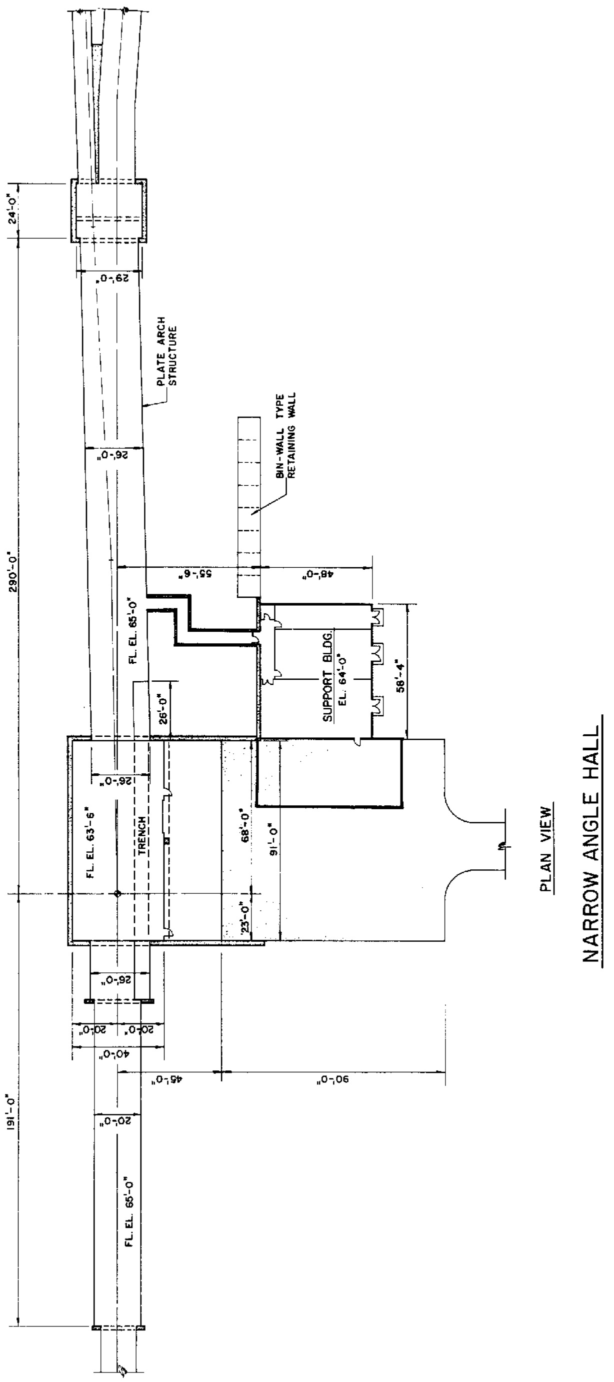

Figure 3-H-1. Schematic of the Narrow Angle Hall and Support Buildings.

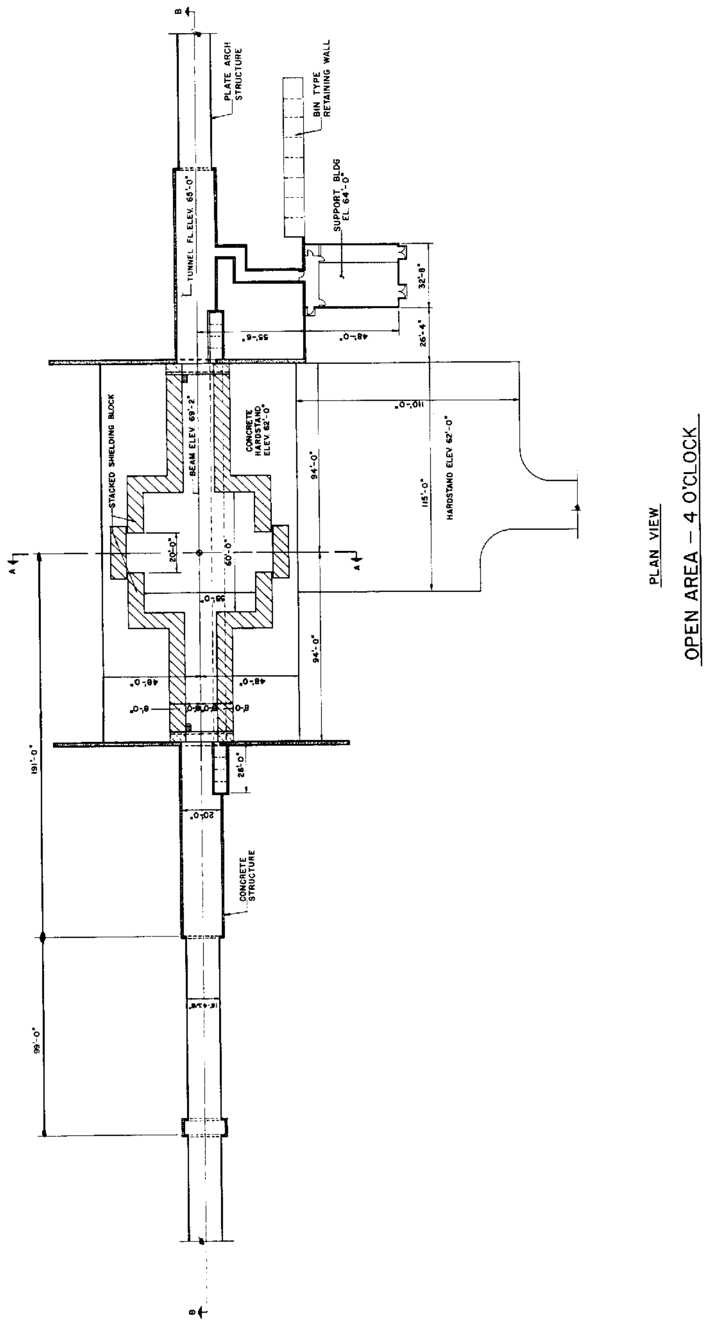

Figure 3-I-1. Schematic of the 4 O'clock Open Area.

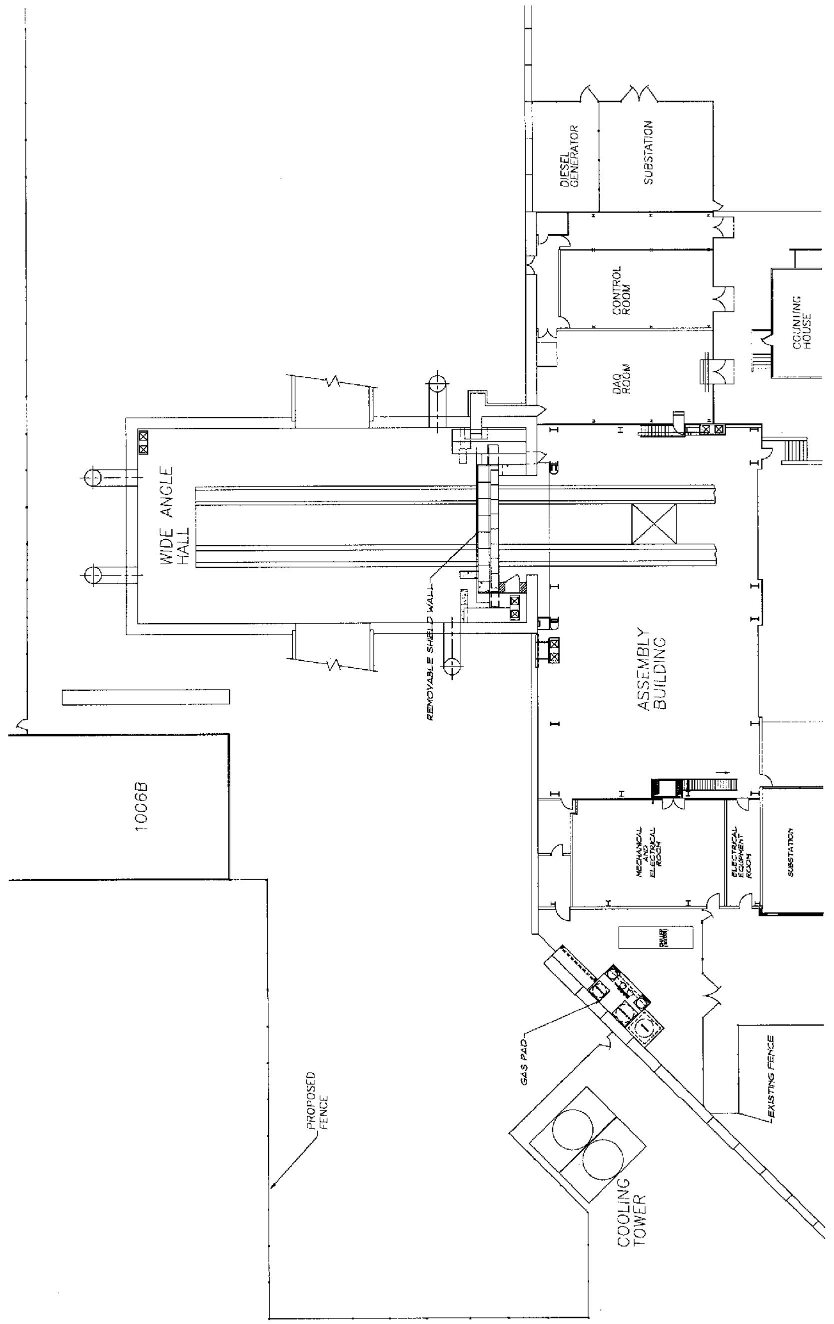

Figure 3-J-1. Schematic of the Wide Angle Hall and Support Buildings.

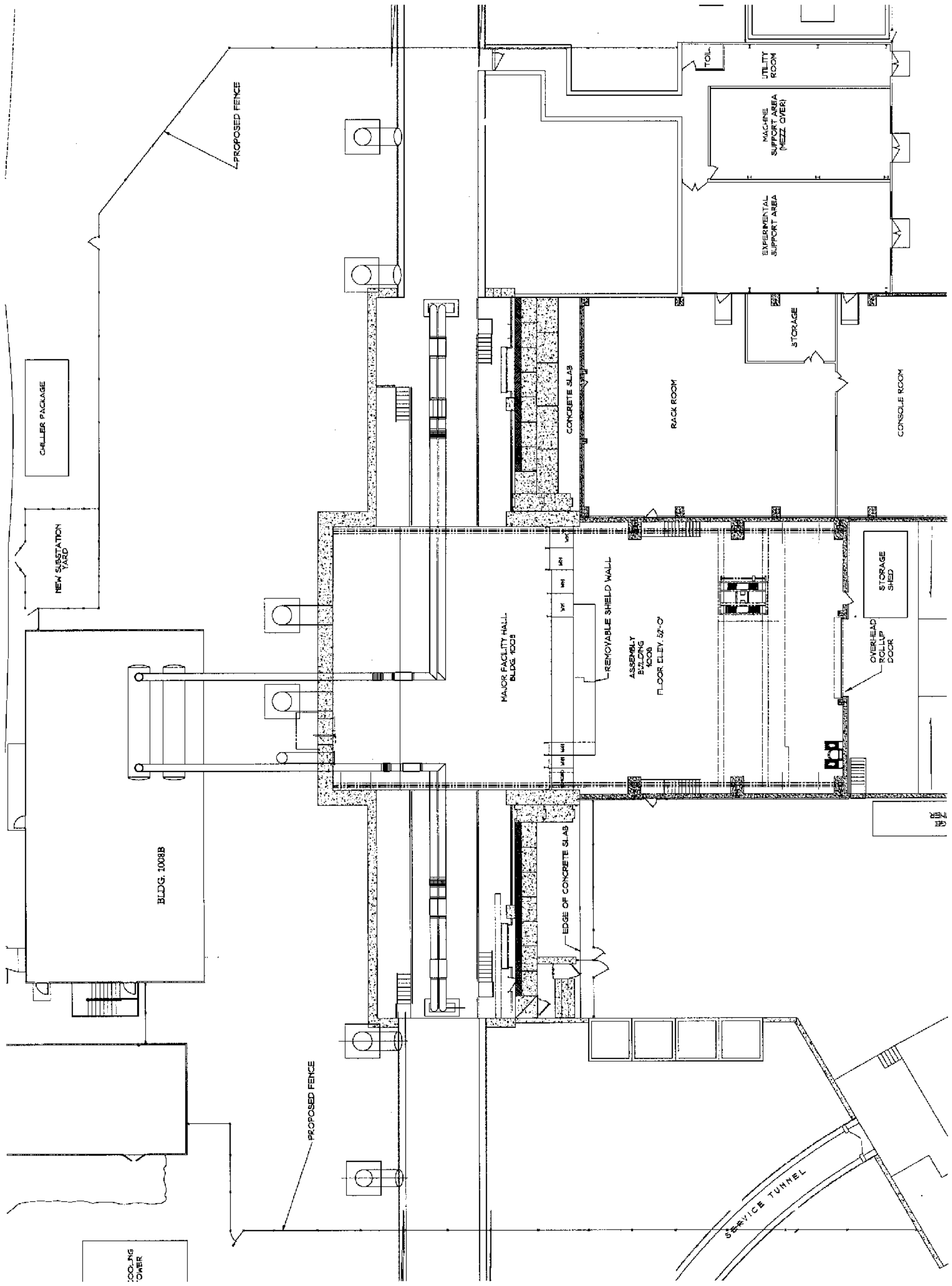

Figure 3-K-1. Schematic of the Major Facility Hall at 8 O'clock.

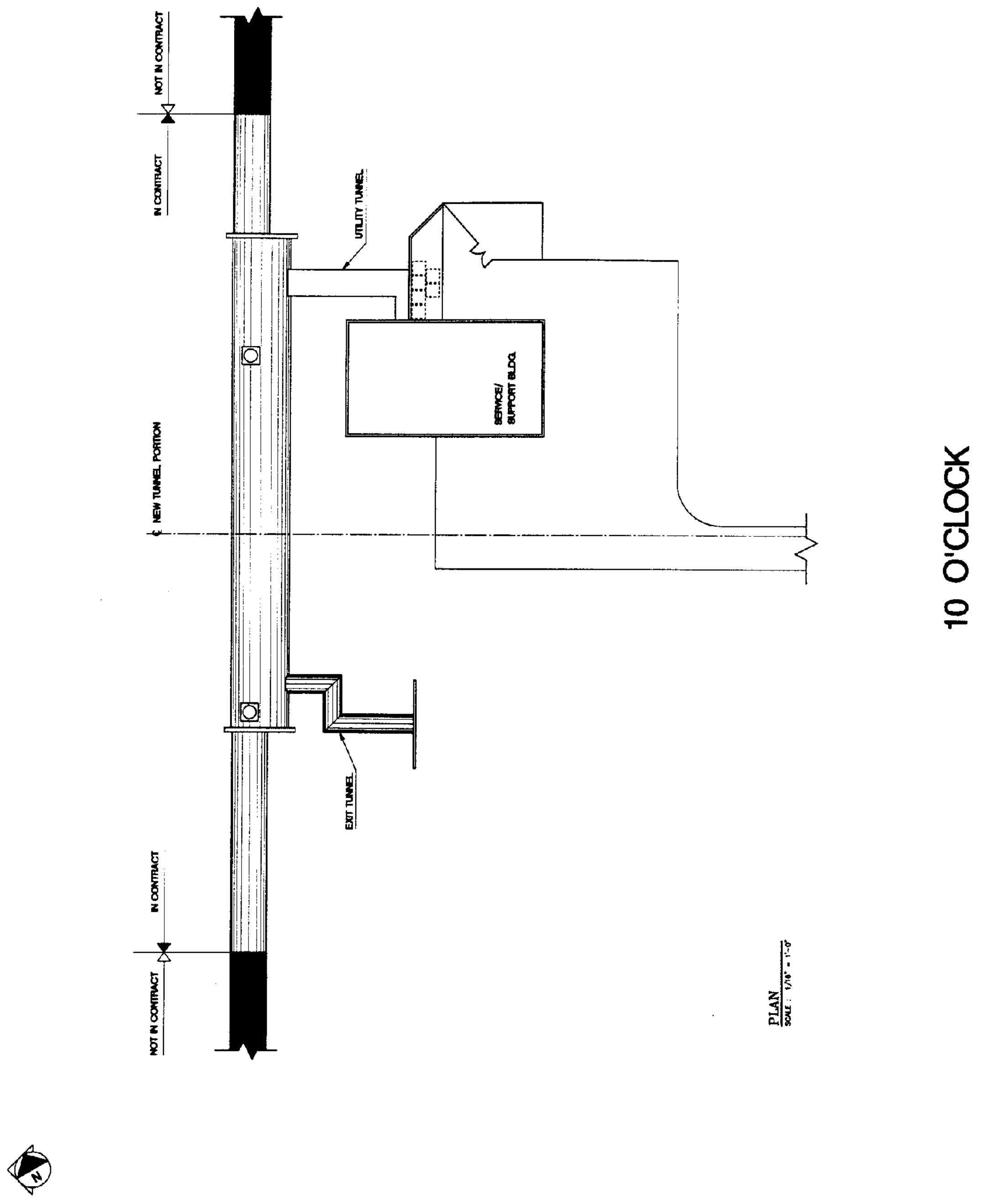

Figure 3-L-1. Schematic of the 10 O'Clock Region.

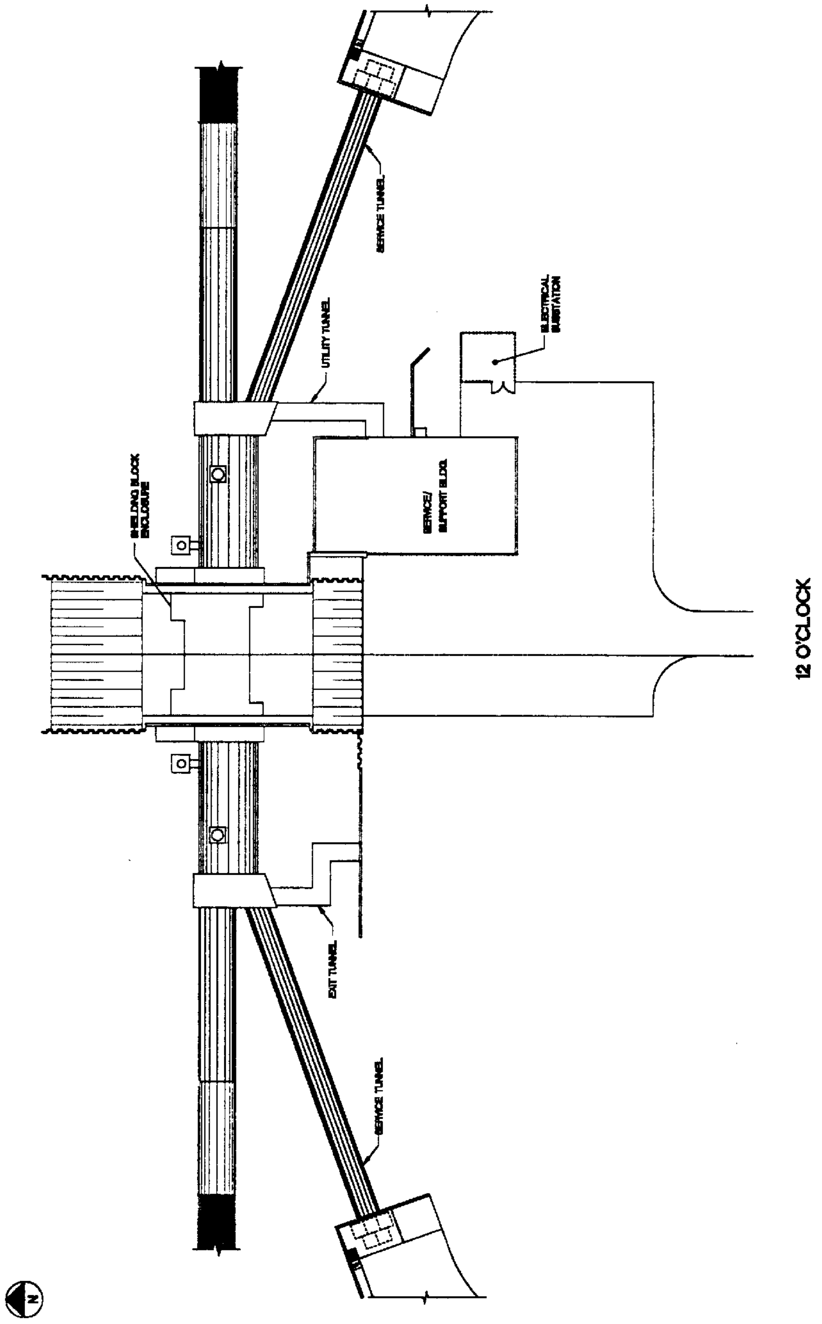

Figure 3-M-1. Schematic of the Major Facility Hall at 12 O'clock.

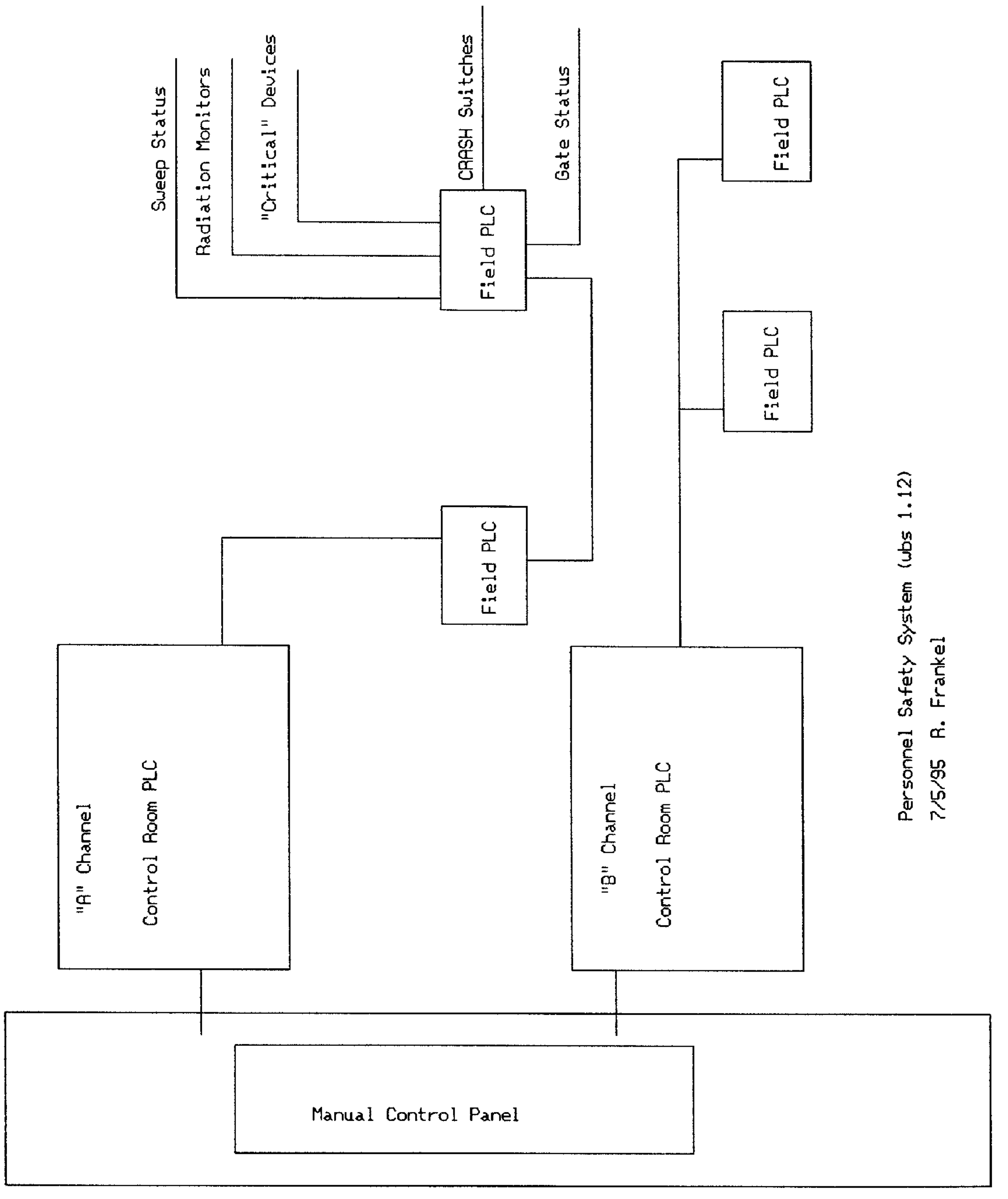

Figure 3-O-1. Personnel Safety System Block Diagram.

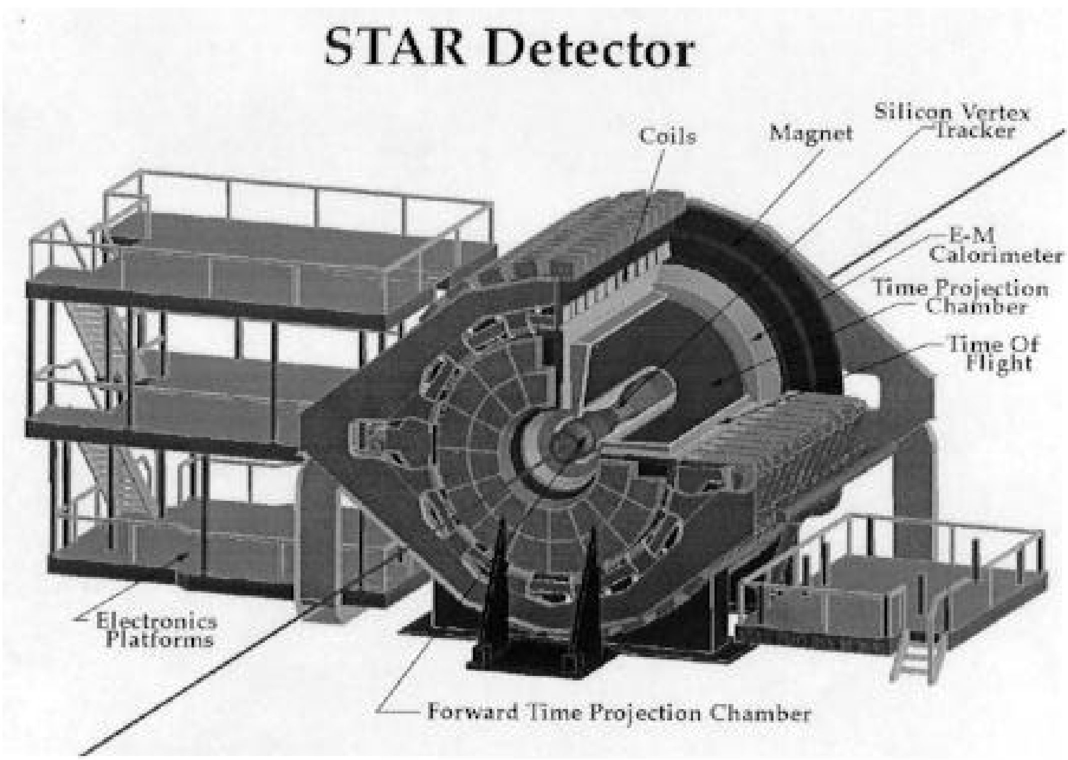

Figure 3-T-1. Cutaway View of the STAR Detector.

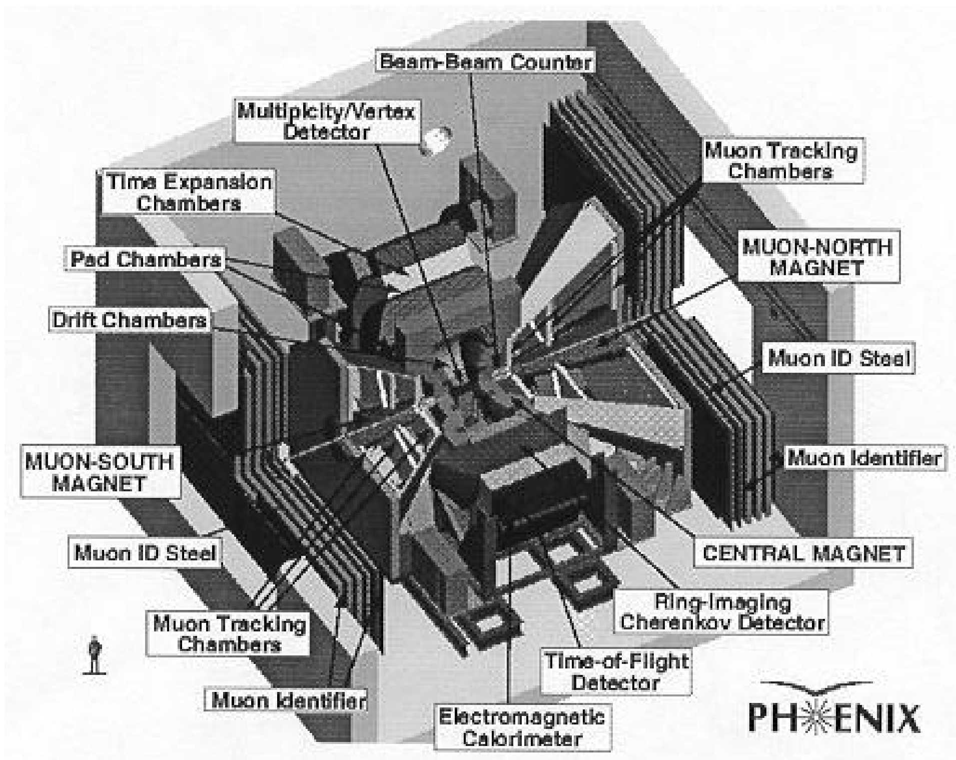

Figure 3-U-1. A cut-away view of PHENIX with major systems labeled.

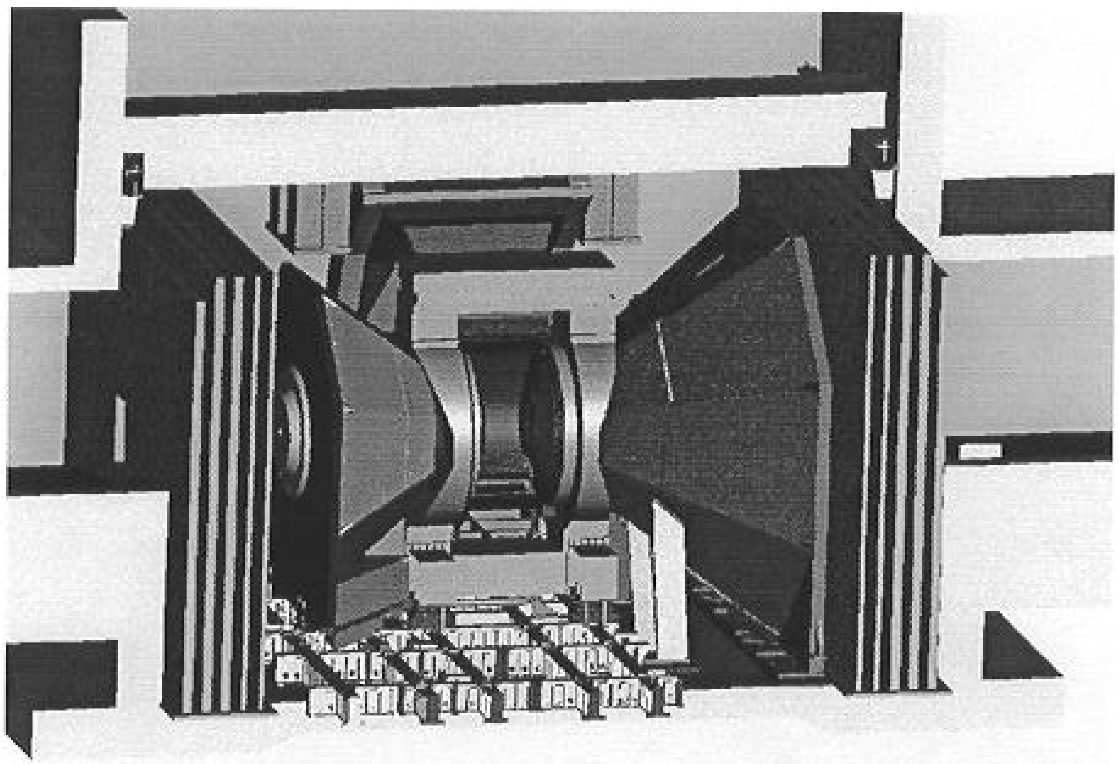

Figure 3-U-2. A 3D rendering of major elements of the PHENIX experiment in the Collision Hall of the PEH with the shield wall removed. The drawing shows the west detector carriage, central magnet, the north and south Muon Arms and the Muon ID steel. A system of tracks for moving PHENIX elements is also shown. The sketch illustrates the close proximity of detector components.